Health Hazard Evaluation of Deepwater Horizon Response Workers

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Health Hazard Evaluation Interim Report 4
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DEPARTMENT OF HEALTH AND HUMAN SERVICES · USA
CDC Workplace Safety and Health
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The cover photo shows support vessels spraying water on the flare side of the Q-4000 to prevent excessive heating of the ship's hull. The Q-4000 was part of the oil spill containment system that was burning oil and gas coming from the damaged Deepwater Horizon blowout preventer in the Gulf of Mexico: June 2010.

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service

National Institute for Occupational Safety and Health
Robert A. Taft Laboratories
4676 Columbia Parkway
Cincinnati OH 45226-1998

11 August 2010
HETA 2010-0115

Fred Tremmel
Deepwater Horizon ICP
1597 Highway 311
Houma, LA 70395

Dear Mr. Tremmel:

On May 28, 2010, the National Institute for Occupational Safety and Health (NIOSH) received a request from BP for a health hazard evaluation (HHE). The request asked NIOSH to evaluate potential exposures and health effects among workers involved in Deepwater Horizon Response activities. NIOSH sent an initial team of HHE investigators on June 2, 2010, to begin the assessment of off-shore activities. To date, more than three dozen HHE investigators have been on-scene.

This letter is the fourth in a series of interim reports. As this information is cleared for posting, we will make it available on the NIOSH website (www.cdc.gov/niosh/hhe). When all field activity and data analyses are complete we will compile the interim reports into a final report.

This report (Interim Report #4) includes several discrete components of our investigation. For each, we provide background, describe our methods, report the findings, and provide conclusions and, where appropriate, interim recommendations. The components included in this report are as follows:

- 4A – Evaluation of Vessels of Opportunity (VoOs) June 10–20, 2010
- 4B – Evaluation of Health Effects in Workers Performing Oil Skimming from Floating City #1, June 19–23, 2010
- 4C – Evaluation of Source Control Vessels Development Driller II and Discoverer Enterprise, June 21-23, 2010

Thank you for your cooperation with this evaluation. If you have any questions, please do not hesitate to contact me at 513.841.4382 or atepper@cdc.gov.

Sincerely yours,

Allison Tepper

Allison Tepper, PhD
Chief
Hazard Evaluations and Technical
Assistance Branch
Division of Surveillance, Hazard
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3 Enclosures

cc:
Mr. David Dutton, BP
Dr. Richard Heron, BP
Dr. Kevin O'Shea, BP
Mr. Joe Gallucci, BP
Ms. Ursula Gouner, Transocean
CDR Laura Weems, USCG
Mr. Clint Guidry, LA Shrimp Association
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Dr. Raoul Ratard, LA DHHS
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Interim Report #4A
Evaluation of Vessels of Opportunity (VoOs), June 10–20, 2010

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Introduction

The Vessels of Opportunity (VoO) program was established by BP in response to the April 20, 2010, Deepwater Horizon explosion and resultant oil spill in the Gulf of Mexico. As part of this program, local vessel owners contracted their boats to conduct a variety of oil spill response activities including booming and skimming operations, supporting on-site burning of surface oil, tar ball recovery, and providing transportation of supplies and personnel [BP 2010]. During June 10–20, 2010, NIOSH industrial hygienists conducted industrial hygiene assessments on six fishing and shrimping trawlers in the VoO program that were contracted by BP to remove surface oil by booming and skimming. These trawlers typically ranged in size from 20 feet to more than 65 feet in length. On days when oil was not present on the water surface in the areas to which these vessels were assigned, the vessel captains often directed their vessels through patches of foam (described by the crew as "dispersant foam") found on the sea surface to break them up. The vessels were typically staffed by a captain and 1–2 deckhands who stayed on the boat and 1–2 responders responsible for doing oil clean-up work on the VoOs. These responders were contract employees and were transported to the VoOs by crew boats on a daily basis.

The VoOs evaluated were assigned under Group 1 Command which was divided into five task forces, each of which was composed of five strike teams. Each strike team had five VoOs with a designated strike team leader. The five task forces in Group 1 Command were located across a large geographic area of the Gulf of Mexico, specifically from Breton Sound, Louisiana to the east of the southwest pass of the Mississippi River. The VoOs were required to be out to sea from 6:00 a.m.to 6:00 p.m. scouting for oil and conducting clean-up work when oil was discovered. The vessels typically traveled at speeds of less than 3.5 knots when scouting oil and traveled even slower (1–1.5 knots) when booms were used to skim oil. Because of their size, most VoOs stayed within a three nautical mile zone from shore. VoOs greater than 65 feet in length could travel beyond this three nautical mile zone. The VoOs docked overnight in safe harbors near the shore.

In addition to the VoOs, each task force had an Off Shore Vessel (OSV) that stayed anchored out at sea. The OSVs are greater than 150 feet in length and have large open decks. The OSVs stored the clean-up supplies used by the VoOs including personal protective equipment (PPE), fuel, and water and were responsible for distributing these items to the VoOs. They also stored on their decks the used absorbent booms and other contaminated materials used by VoO workers during oil clean-up work.

Group 1 Command was based at Floating City #1 and was responsible for providing the VoOs with the responders, food, and other supplies as needed. Floating City #1 was located at the north tip of Baptiste Collette Bayou and had the capability of housing 225 personnel. On a typical morning, the responders met at 5:30 a.m. to discuss safety issues of importance, followed by transport to their respective VoOs by a number of crew boats. Upon completion of the work shift, the responders were brought back by

crew boats to the Floating City #1. The total time the responders spent traveling on the crew boats to and from their assigned VoOs typically ranged from 4–6 hours per day.

Responders and VoO personnel who conducted oil clean-up work were provided and required to wear yellow POSIWEAR®UB™ chemical protective suits, disposable nitrile gloves, 12" PIP ProCoat® PVC dipped chemical resistant gloves, steel toe rubber boots, safety glasses, hard hats, and personal flotation devices. In addition, nitrile gloves were required when cleaning the hard booms with diluted chemical cleaners.

Six different VoOs were evaluated by NIOSH industrial hygienists from June 10–20, 2010. General area (GA) and personal breathing zone (PBZ) air sampling was conducted on June 10, 2010 on board the Miss Brandy; on June 15, 2010 on board the Talibah II and the Pelican; on June 16, 2010 on board the North Star and the St. Martin; and on June 20, 2010 on board the Miss Carmen. Specifications for each VoO are shown below in Table 1. The determinations on which strike teams and VoOs to which the NIOSH industrial hygienists would be directed was made by Group 1 Command staff based on oil collection reports from the previous few days.

Table 1. Specifications of VoOs on which air sampling was conducted from June 10–20, 2010

Sampling Date	VoO	Task Force/ Strike Team	Dimensions (feet)	Personnel	Fuel	Smoking Inside/Outside Cabin
6/10/2010	Miss Brandy	TF-5/ST-5	72' x 24'	Captain, 2 deckhands, 2 responders	Diesel	Yes/Yes
6/15/2010	Talibah II	TF-5/ST-1	38.5' x 16'	Captain, deckhand, responder	Diesel	No/No
6/15/2010	Pelican	TF-5/ST-4	47' x 18'	Captain, 2 deckhands, responder	Diesel	Yes/Yes
6/16/2010	North Star	TF-5/ST-3	62.7' x 20'	Captain, 2 deckhands	Diesel	No/No
6/16/2010	St. Martin	TF-5/ST-5	60' x 20'	Captain, 2 deckhands	Diesel	Yes/Yes
6/20/2010	Miss Carmen	TF-4/ST-2	46' x 19'	Captain, deckhand, responder	Diesel	No/Yes

While coordinating and preparing for the evaluations on board the VoOs, the NIOSH industrial hygienists were informed that VoOs encountered oil patches around the Gulf of Mexico in a sporadic manner due to the oil movement caused by Gulf currents. During the evaluation on June 10, 2010, the captain of the Miss Brandy informed the NIOSH industrial hygienists that they had not encountered oil in over a week and half. The vessel was tasked to scout for oil in a specific grid location on the east side of the southwest pass of the Mississippi River. On the day of the NIOSH evaluation, Miss Brandy did not encounter oil. However, the vessel did encounter what was described by the personnel as "residual dispersant foam" present on the sea surface. The vessel spent time breaking up the long foam patches

by driving through them. Other VoOs in the nearby area were also performing the same operation. The captain, deckhands, and responders spent most of their work shift inside the air conditioned cabin.

NIOSH industrial hygienists were transported to different VoOs on June 15, 16, and 20, 2010, to conduct evaluations during oil booming and clean-up activities on these vessels. However, similar to the evaluation on the Miss Brandy, no oil was encountered by these VoOs during the times when NIOSH industrial hygienists were on board. The vessels did encounter similar foam patches which were broken up by driving the boats through it. During these evaluations, VoO personnel and responders on the vessels spent most of their time in the air conditioned cabins.

Evaluation

NIOSH investigators conducted longer-term PBZ and GA air sampling on six different VoOs from June 10–20, 2010. The sampling period for longer-term air samples on each vessel was 4–6 hours because NIOSH industrial hygienists were directed to specific VoOs later in the morning of the day of the evaluation once coordinates of the VoOs were determined by Group 1 Command staff. Additionally, the responders were picked up approximately 2–3 hours before the end of the work day to allow for adequate time to travel back to Floating City #1. Although sampling times were less than the actual twelve hour shift times, the air sampling data represents worker exposures during the time when the responders were present on the VoOs. Shorter-term air samples evaluating specific tasks were not collected due to the lack of oil clean-up work activities on the days of the NIOSH evaluations.

To evaluate the presence of volatile organic compounds (VOCs), NIOSH investigators used integrated air sampling with a variety of sampling media, including multi-sorbent thermal desorption tubes followed by thermal desorption/gas chromatography-mass spectrometry (NIOSH Method 2549) and activated charcoal tubes [NIOSH 2010]. Results of the thermal desorption tube air samples were used to select specific VOCs for quantitation on PBZ and GA air samples collected using charcoal tubes. Other chemicals measured in PBZ or GA air samples using integrated air sampling techniques included propylene glycol (a component of the dispersant), diesel exhaust, mercury (a possible component of crude oil), and the benzene soluble fraction of total particulate samples. Direct reading measurements were made for carbon monoxide (CO) and hydrogen sulfide (H_2S). The sampling and analytical methods used are provided in Table 2.

Results

Table 3 contains a summary of the relevant occupational exposure limits (OELs) to which results were compared. Table 4 presents temperature and relative humidity (RH) measurements collected during the days when air sampling was conducted by the NIOSH industrial hygienists. The deck temperatures for the six VoOs ranged from 67˚F–106˚F and the RH ranged from 30%–87%. The temperature inside the vessels' cabins ranged from 66˚F–89˚F and the RH ranged from 29%–72%.

Volatile Organic Compounds

Seven thermal desorption tube area air samples were collected to screen for VOCs on five of the six VoOs. The screening samples collected during these sampling visits contained a variety of substances. The major compounds detected on all vessels were C_9 to C_{15} aliphatic hydrocarbons (straight and branched alkanes). Additional compounds detected included benzene, toluene, xylenes, napthalenes, and other substances. Limonene was also found on screening samples collected on board the Pelican and the North Star.

Based on the results of the thermal desorption tube screening samples, 19 PBZ and GA charcoal tube air samples were quantitated for benzene, ethyl benzene, limonene, naphthalene, toluene, total hydrocarbons (THC) (as hexane), and xylenes. Results are shown in Tables 5–10. Air concentrations of chemicals for which the air samples were analyzed were all well below their applicable OELs. Of the six PBZ samples (collected on a deckhand and a responder on the Pelican and on a deckhand on the St. Martin), limonene, THC, toluene, xylenes, and ethyl benzene were present above the minimum quantifiable concentrations (MQC) (see Tables 7 and 9). Personnel on both VoOs spent time inside the cabin as well as outdoors but did not engage in oil clean-up related tasks. The highest THC PBZ concentration was 6.0 milligrams per cubic meter (mg/m^3) and was collected on a deckhand on board the Pelican. The highest THC GA concentration on any of the six vessels was 6.5 mg/m^3 and was collected inside the cabin of the Pelican. The THC GA concentrations were greater inside the cabins of North Star and St. Martin when compared to the outside concentrations. Although there is no OEL specifically for THCs, OELs for petroleum distillates and kerosene (two mixtures containing a similar range of hydrocarbons as was found on the initial thermal tube air samples) are 350 mg/m^3 as a work shift time weighted average as shown in Table 2. Limonene is one of the ingredients in cleaning agents, which might explain its presence in the air samples. Even on an additive basis, for any given exposure period, the mixtures of chemicals measured in the air are a fraction (<10%) of the acceptable levels.

One GA air sample collected on Miss Carmen was quantitated for 2-butoxyethanol, dipropylene glycol butyl ether, and dipropylene glycol methyl ether (potential components in cleaners and oil dispersant). None of the analytes were present in concentrations greater than their respective minimum detectable concentrations (MDC) (Table 10).

Propylene Glycol

The NIOSH industrial hygienists collected seven GA air samples for propylene glycol, a component of Corexit 9500A (Nalco Company, Sugar Land, Texas), the dispersant in use at the time of the NIOSH evaluation. One GA air sample was collected on the deck of each VoO. In addition, a NIOSH industrial hygienist collected one GA air sample inside the cabin of the North Star. Propylene glycol was not detected in six of the air samples and was present below the MQC in one air sample (Tables 5–10).

Diesel Exhaust

Emissions from diesel engines used to power the vessels are complex mixtures of gases and particulates. NIOSH uses elemental carbon (EC) as a surrogate index of exposure because the sampling and analytical method for EC is very sensitive, and a high percentage of diesel particulate (80%–90%) is EC. In comparison, tobacco smoke particulate (a potential interference when measuring diesel exhaust) is composed primarily of organic carbon (OC). Although OSHA and NIOSH have established OELs for some of the individual components of diesel exhaust (i.e., nitrogen dioxide, CO), neither agency has established an OEL for EC. However, the California Department of Health Services' Hazard Evaluation System & Information Service (HESIS) guideline for diesel exhaust particles (measured as EC) is 20 micrograms per cubic meter ($\mu g/m^3$) for an 8-hour TWA. One air sample for diesel exhaust was collected on the deck of each of the VoOs. As shown in Tables 5–10, EC concentrations ranged from 1.4–9.1 $\mu g/m^3$, below the HESIS guideline. The OC concentrations ranged from less than 10–31 $\mu g/m^3$. Furthermore, diesel exhaust was not a substantial part of these sample results because the ratio of EC to total carbon (the sum of EC + OC) ranged from 4.3%–48%, which is below the expected 60%–80% of EC to total carbon typically reported in diesel exhaust.

Mercury
The NIOSH industrial hygienists collected five GA air samples for mercury of which four were collected on the decks of different VoOs and one was collected inside the cabin of North Star. Mercury air samples were not collected on the Miss Carmen. No mercury was detected in the five area air samples. The MDCs ranged up to 0.00005 mg/m^3, well below the most protective OEL of 0.025 mg/m^3.

Benzene Soluble Total Particulate Fraction
Two PBZ air samples (collected on deckhands on the Pelican and the St. Martin) and eight GA air samples (collected on all six VoOs) were collected for total particulates with the particulate fraction analyzed for benzene soluble components (to separate out contributions from substances like salts from the sea water) as an indicator of oil mist exposures (see Tables 5–10). Three of these eight GA air samples were collected inside the cabins of the Pelican, the North Star, and the St. Martin. None of the air samples contained detectable concentrations of benzene soluble particulates and none of the air samples returned results above the MQC for total particulates.

Carbon Monoxide and Hydrogen Sulfide
Tables 5–10 include a summary of the direct reading measurements for CO and H_2S. Carbon monoxide, a component of incomplete combustion, possibly from the diesel engines, was monitored on the deck and inside the cabins of various VoOs. Peak concentrations of CO ranged up to 15 parts per million (ppm), with the highest TWA of 6 ppm, well below OELs. Hydrogen sulfide was not detected on six area samples collected on the VoOs.

Summary

During this evaluation, the VoOs on which the NIOSH industrial hygienists were present spent most of their time scouting for oil and breaking up foam patches. Since no oil was encountered by these VoOs on these days, NIOSH investigators did not observe any oil clean-up work. The PBZ and area air concentrations of the measured compounds were all well below OELs.

Recommendations

The NIOSH industrial hygienists noted that employees were provided adequate PPE necessary to conduct their jobs. However, the potential for dermal contact with the weathered oil and cleaning agents exists when performing booming and skimming tasks. Due to this potential, it is recommended that all personnel conducting oil clean-up work on the VoOs ensure that the provided PPE is correctly worn during such work to prevent possible dermal exposures.

While respiratory protection was not a required component of PPE for the deckhands or responders conducting this oil clean-up work, a NIOSH industrial hygienist on one of the VoOs was shown a 3M™ half-mask respirator with organic vapor/acid gas P100 cartridges by one of the deckhands. The deckhand described the respirator as a part of the supplies provided to the boat. However, it was the only respirator provided to the vessel which had three permanent workers stationed on it. The deckhand noted that they were told that more respirators would be provided but were not delivered. It is recommended that any PPE determined to be needed by the oil spill command staff be provided in sufficient quantities for all workers present on the vessels. If respiratory protection is ever determined to be required as part of the PPE ensemble, all the elements of the OSHA Respiratory Protection Standard (29 CFR 1910.134), including fit testing, medical clearance, and proper training in the use of the respirators should be followed.

While on one of the VoOs, a NIOSH industrial hygienist inquired about the use of cleaners provided to the VoOs to clean their boats and booms. The deckhand responded that instructions had been provided to him for the proper dilution and application of the cleaner. NIOSH industrial hygienists recommend that proper training and instructions in the use of chemical cleaners be continued and that all VoO personnel working with such chemicals follow these instructions throughout the course of their work.

The NIOSH industrial hygienists observed widespread use of tobacco products, particularly cigarettes among the worker populations on most of the VoOs evaluated. Cigarette use by workers outside on the decks of vessels as well as inside cabins was observed. Smoking is the single most preventable cause of disease, disability, and death in the United States; an estimated 443,000 people die prematurely from smoking or exposure to secondhand smoke, and another 8.6 million have a serious illness caused by smoking [CDC 2010]. Eliminating cigarette smoking among Deepwater Horizon response workers on the VoOs would be the most desirable recommendation. From all the research on cigarette smoking, we know that quitting smoking has immediate as well as long-term benefits for smokers and those around them.

Acknowledgments

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Table 2. Analytical methods used for substances evaluated during the June 10–20, 2010 VoOs evaluation

Analyte	Method
Benzene	NMAM 1501*†
Benzene soluble fraction of total particulates	NMAM 5042
2-Butoxyethanol	NMAM1403‡
Carbon monoxide	Direct reading—GasAlert CO Extreme, BW Technologies Ltd., Calgary, Canada
Diesel exhaust (elemental carbon, organic carbon, total carbon)	NMAM 5040
Dipropylene glycol butyl ether	NMAM1403‡
Dipropylene glycol methyl ether	NMAM1403‡
Ethyl benzene	NMAM 1501†
Hydrogen sulfide	Direct reading—GasAlert H_2S Extreme, BW Technologies Ltd., Calgary, Canada
Limonene	NMAM 1501†
Mercury	NMAM 6009
Naphthalene	NMAM 1501†
Propylene glycol	NMAM 5523
Relative humidity	Direct reading—HOBO® H8 ProSeries, Onset Computer Corporation, Bourne, Massachusetts
Temperature	Direct reading—HOBO® H8 ProSeries, Onset Computer Corporation, Bourne, Massachusetts
Toluene	NMAM 1501†
Total Hydrocarbons	NMAM 1501†
Volatile organic compounds (Screening)	NMAM 2549 and EPA TO-15§
Xylenes (Total)	NMAM 1501†

*National Institute for Occupational Safety and Health (NIOSH) Manual of Analytical Methods [NIOSH 2010]
†Analysis for selected volatile organic compounds by an adaptation of the method
‡Analysis by an adaptation of the method
§Environmental Protection Agency [EPA 1999]

Table 3. Occupational exposure limits for substances evaluated during the June 10–20, 2010 VoOs evaluation

Chemical	NIOSH REL[a]	OSHA PEL[b]	ACGIH TLV[c]	AIHA WEEL[d]
Benzene	0.1 ppm TWA[e] 1 ppm STEL[g]	1 ppm TWA 5 ppm STEL 0.5 ppm Action Level	0.5 ppm TWA 2.5 ppm STEL	N/A[f]
Benzene soluble fraction of total particulate	N/A	N/A	0.5 mg/m^3 TWA[h]	N/A
2-Butoxyethanol	5 ppm TWA	50 ppm TWA	20 ppm TWA	N/A
Carbon monoxide	35 ppm TWA 200 ppm Ceiling	50 ppm TWA	25 ppm TWA	N/A
Diesel exhaust (as elemental carbon)[i]	N/A	N/A	N/A	N/A
Dipropylene glycol butyl ether	N/A	N/A	N/A	N/A
Dipropylene glycol methyl ether	100 ppm TWA 150 ppm STEL	100 ppm TWA	100 ppm TWA 150 ppm STEL	N/A
Ethyl benzene	100 ppm TWA 125 ppm STEL	100 ppm TWA	100 ppm TWA[j] 125 ppm STEL	N/A
Hydrogen sulfide	10 ppm Ceiling (10 min)	20 ppm Ceiling[k]	1 ppm TWA 5 ppm STEL	N/A
Limonene	N/A	N/A	N/A	30 ppm
Mercury	0.05 mg/m^3 TWA[l]	0.1 mg/m^3 TWA[m]	0.025 mg/m^3 TWA[m]	N/A
Naphthalene	10 ppm TWA 15 ppm STEL	10 ppm TWA	10 ppm TWA 15 ppm STEL	N/A
Propylene glycol	N/A	N/A	N/A	10 mg/m^3
Toluene	100 ppm TWA 150 ppm STEL	200 ppm TWA 300 ppm Ceiling 500 ppm Peak (10 min max.)	20 ppm TWA	N/A
Total hydrocarbons	350 mg/m^3 TWA 1800 mg/m^3 Ceiling (15 min) (Petroleum distillates)	2000 mg/m^3 TWA (Petroleum distillates as naphtha)	200 mg/m^3 TWA (Kerosene as total hydrocarbon vapor)	N/A

Table 3. Occupational exposure limits for substances evaluated during the June 10–20, 2010 VoOs evaluation (continued)

Chemical	NIOSH REL[a]	OSHA PEL[b]	ACGIH TLV[c]	AIHA WEEL[d]
Xylenes	100 ppm TWA 150 ppm STEL	100 ppm TWA	100 ppm TWA 150 ppm STEL	N/A

[a]National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL) [NIOSH 2005]
[b]Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) [29 CFR 1910]
[c]American Conference of Governmental Industrial Hygienists® (ACGIH) threshold limit value® (TLV) [ACGIH 2010]
[d]American Industrial Hygiene Association (AIHA) Workplace Environmental Exposure Level (WEEL) [AIHA 2009]
[e]TWA = time weighted average
[f]N/A = not applicable
[g]STEL = short term exposure limit
[h]This OEL is for asphalt (bitumen) fume as benzene soluble aerosol but was considered appropriate because this sampling was intended to differentiate between petroleum associated particulate and background particulate.
[i]California Department of Health Services' Hazard Evaluation System & Information Service (HESIS) guideline for diesel exhaust particles (measured as elemental carbon [EC]) is 20 µg/m^3 for an 8-hour TWA [CDHS 2002]
[j]Proposed to be changed to 20 ppm TWA and STEL eliminated [ACGIH 2010]
[k]Exposures shall not exceed with the following exception: if no other measurable exposure occurs during the 8-hour work shift, exposures may exceed 20 ppm, but not more than 50 ppm (peak), for a single time period up to 10 minutes
[l]Elemental form
[m]Elemental and inorganic forms

Table 4. Environmental conditions during the June 10–20, 2010 VoOs evaluation*		
Vessel	**Temperature (°F)***	**Relative Humidity (%)***
June 10, 2010		
Miss Brandy (Captain's Cabin)	71	54–55; 54
Miss Brandy (Dining Area)	71	55
Miss Brandy (Middeck above pulley)	70	56–57; 56
June 15, 2010		
Talibah II (Rear deck center)	87–91; 89	55–71; 64
Talibah II (Captain's cabin)	87–89; 88	62–66; 63
Pelican (In Cabin)	83–89; 85	29–61; 39
Pelican (On deck)	89–95; 93	48–65; 55
June 16, 2010		
North Star (Inside cabin)	66–77; 68	43–70; 55
St. Martin (On deck)	80–106; 94	30–72; 52
St. Martin (In cabin)	77–81; 81	37–72; 45
June 20, 2010		
Miss Carmen (Rear deck center)	67–92; 89	61–87; 69

*Reported as range; average
Hours of monitoring: approximately 9:00 a.m. – 4:00 p.m.

Table 5. Area air concentrations for substances measured on June 10, 2010 on the Miss Brandy

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Area Air Samples				
Starboard side deck	Benzene	341	67.9	<0.001 ppm
Starboard side deck	Benzene	340	68.7	<0.001 ppm
Starboard side deck	Benzene soluble fraction	338	671	<0.04 mg/m^3
Captain's Cabin	Carbon Monoxide	406	N/A	Range: 0–0 ppm; Avg: 0 ppm
Dining Area	Carbon Monoxide	412	N/A	Range: 0–0 ppm; Avg: 0 ppm
Middeck above pulley	Carbon Monoxide	401	N/A	Range: 0–0 ppm; Avg: 0 ppm
Portside of deck	Diesel exhaust	338	670	EC: (2.5 µg/m^3); OC: (31 µg/m^3)
Starboard side deck	Ethyl benzene	341	67.9	<0.0007 ppm
Starboard side deck	Ethyl benzene	340	68.7	<0.0007 ppm
Dining Area	Hydrogen sulfide	412	N/A	0 ppm
Middeck above pulley	Hydrogen sulfide	401	N/A	0 ppm
Portside of deck	Mercury	529	105	<0.00002 mg/m^3
Starboard side deck	Naphthalene	341	67.9	(0.0034 ppm)
Starboard side deck	Naphthalene	340	68.7	(0.0033 ppm)
Portside of deck	Propylene glycol	338	670	<0.001 mg/m^3
Starboard side deck	Toluene	341	67.9	<0.0008 ppm
Starboard side deck	Toluene	340	68.7	<0.0008 ppm
Starboard side deck	Total hydrocarbons	341	67.9	0.37 mg/m^3
Starboard side deck	Total hydrocarbons	340	68.7	0.37 mg/m^3
Starboard side deck	Total particulates	338	671	<0.06 mg/m^3
Starboard side deck	Xylenes	341	67.9	(0.0014 ppm)
Starboard side deck	Xylenes	340	68.7	(0.0014 ppm)

*N/A = not applicable

†Concentrations reported as "<" were not detected; the given value is the minimum detectable concentration

‡Concentrations in parentheses were between the minimum detectable concentration and the minimum quantifiable concentration (parentheses are used to point out there is more uncertainty associated with these values than values above the minimum quantifiable concentration)

Table 6. Area air concentrations for substances measured on June 15, 2010 on the Talibah II

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Area Air Samples				
Rear deck center	Benzene	221	44.6	<0.002 ppm
Rear deck center	Benzene	219	43.3	<0.002 ppm
Rear deck center	Benzene soluble fraction	219	435	<0.2 mg/m^3
Captain's cabin	Carbon Monoxide	234	N/A	Range: 0–6 ppm; Avg: 1 ppm
Rear deck end	Carbon Monoxide	228	N/A	Range: 0–15 ppm; Avg: 2 ppm
Rear deck center	Diesel exhaust	224	446	EC: (1.6 µg/m^3); OC: <20µg/m^3
Rear deck center	Ethyl benzene	221	44.6	<0.001 ppm
Rear deck center	Ethyl benzene	219	43.3	<0.001 ppm
Rear deck end	Hydrogen sulfide	228	N/A	0 ppm
Rear deck center	Limonene	221	44.6	<0.0008 ppm
Rear deck center	Limonene	219	43.3	<0.0008 ppm
Rear deck center	Mercury	220	43.2	<0.00005 mg/m^3
Rear deck center	Naphthalene	221	44.6	<0.0009 ppm
Rear deck center	Naphthalene	219	43.3	<0.0009 ppm
Rear deck center	Propylene glycol	114	224	<0.004 mg/m^3
Rear deck center	Toluene	221	44.6	<0.001 ppm
Rear deck center	Toluene	219	43.3	<0.001 ppm
Rear deck center	Total hydrocarbons	221	44.6	(0.0099 mg/m^3)
Rear deck center	Total hydrocarbons	219	43.3	(0.014 mg/m^3)
Rear deck center	Total particulates	219	435	<0.09 mg/m^3
Rear deck center	Xylenes	221	44.6	<0.002 ppm
Rear deck center	Xylenes	219	43.3	<0.002 ppm

*N/A = not applicable

†Concentrations reported as "<" were not detected; the given value is the minimum detectable concentration

‡Concentrations in parentheses were between the minimum detectable concentration and the minimum quantifiable concentration (parentheses are used to point out there is more uncertainty associated with these values than values above the minimum quantifiable concentration)

Table 7. Personal breathing zone and area air concentrations for substances measured on June 15, 2010 on the Pelican

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Personal Breathing Zone Air Samples—Worker A§				
Deckhand	Benzene soluble fraction	247	480	<0.2 mg/m^3
Deckhand	Total particulates	247	480	(0.18 mg/m^3)
Personal Breathing Zone Air Samples—Worker B§				
Responder	Benzene	215	42.5	<0.002 ppm
Responder	Benzene	214	42.1	<0.002 ppm
Responder	Ethyl benzene	215	42.5	<0.001 ppm
Responder	Ethyl benzene	214	42.1	<0.001 ppm
Responder	Limonene	215	42.5	0.013 ppm
Responder	Limonene	214	42.1	0.0077 ppm
Responder	Naphthalene	215	42.5	<0.0009 ppm
Responder	Naphthalene	214	42.1	<0.0009 ppm
Responder	Toluene	215	42.5	<0.001 ppm
Responder	Toluene	214	42.1	<0.001 ppm
Responder	Total hydrocarbons	215	42.5	0.092 mg/m^3
Responder	Total hydrocarbons	214	42.1	0.059 mg/m^3
Responder	Xylenes	215	42.5	<0.002 ppm
Responder	Xylenes	214	42.1	<0.002 ppm
Personal Breathing Zone Air Samples—Worker C§				
Deckhand	Benzene	234	46.7	(0.0027 ppm)
Deckhand	Benzene	232	46.0	(0.0025 ppm)
Deckhand	Ethyl benzene	234	46.7	0.0084 ppm
Deckhand	Ethyl benzene	232	46.0	0.0085 ppm
Deckhand	Limonene	234	46.7	0.085 ppm
Deckhand	Limonene	232	46.0	0.085 ppm
Deckhand	Naphthalene	234	46.7	(0.013 ppm)
Deckhand	Naphthalene	232	46.0	(0.012 ppm)
Deckhand	Toluene	234	46.7	0.015 ppm
Deckhand	Toluene	232	46.0	0.016 ppm
Deckhand	Total hydrocarbons	234	46.7	5.8 mg/m^3
Deckhand	Total hydrocarbons	232	46.0	6.0 mg/m^3
Deckhand	Xylenes	234	46.7	0.035 ppm
Deckhand	Xylenes	232	46.0	0.035 ppm

Table 7. Personal breathing zone and area air concentrations for substances measured on June 15, 2010 on the Pelican (continued)

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Area Air Samples				
In Cabin	Benzene	236	46.0	(0.0031 ppm)
On deck	Benzene soluble fraction	249	497	<0.2 mg/m^3
In Cabin	Benzene soluble fraction	249	490	<0.2 mg/m^3
On deck	Carbon Monoxide	255	N/A	Range: 0–13 ppm; Avg: 3 ppm
On deck	Diesel exhaust	255	502	EC: (2.8 µg/m^3); OC: <20 µg/m^3
In Cabin	Ethyl benzene	236	46.0	0.0095 ppm
On deck	Hydrogen sulfide	256	N/A	0 ppm
In Cabin	Limonene	236	46.0	0.082 ppm
On deck	Mercury	236	46.2	<0.00004 ppm
In Cabin	Naphthalene	236	46.0	(0.012 ppm)
On deck	Propylene glycol	251	490	<0.002 mg/m^3
In Cabin	Toluene	236	46.0	0.017 ppm
In Cabin	Total hydrocarbons	236	46.0	6.5 mg/m^3
On deck	Total particulates	249	497	<0.08 mg/m^3
In Cabin	Total particulates	249	490	<0.08 mg/m^3
In Cabin	Xylenes	236	46.0	0.039 ppm

*N/A = not applicable

†Concentrations reported as "<" were not detected; the given value is the minimum detectable concentration

‡Concentrations in parentheses were between the minimum detectable concentration and the minimum quantifiable concentration (parentheses are used to point out there is more uncertainty associated with these values than values above the minimum quantifiable concentration)

§Worker smoked

Table 8. Area air concentrations for substances measured on June 16, 2010 on the North Star

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Area Air Samples				
Inside Cabin	Benzene	218	43.3	<0.002 ppm
Inside Cabin	Benzene	217	44.1	<0.002 ppm
Outside rear center	Benzene	207	41.5	<0.002 ppm
Outside rear center	Benzene	208	40.6	<0.002 ppm
Inside Cabin	Benzene soluble fraction	223	442	<0.2 mg/m^3
Outside rear center	Carbon Monoxide	209	N/A	Range: 0–9 ppm; Avg: 6 ppm
Inside Cabin	Carbon Monoxide	214	N/A	Range: 0–0 ppm; Avg: 0 ppm
Outside rear center	Diesel exhaust	207	416	EC: (1.5 µg/m^3); OC: <20µg/m^3
Inside Cabin	Ethyl benzene	218	43.3	<0.001 ppm
Inside Cabin	Ethyl benzene	217	44.1	<0.001 ppm
Outside rear center	Ethyl benzene	207	41.5	<0.001 ppm
Outside rear center	Ethyl benzene	208	40.6	<0.001 ppm
Outside rear center	Hydrogen sulfide	209	N/A	0 ppm
Inside Cabin	Limonene	218	43.3	0.011 ppm
Inside Cabin	Limonene	217	44.1	0.011 ppm
Outside rear center	Limonene	207	41.5	(0.0010 ppm)
Outside rear center	Limonene	208	40.6	(0.0019 ppm)
Inside Cabin	Mercury	219	44.2	0.00005 mg/m^3
Inside Cabin	Naphthalene	218	43.3	<0.0009 ppm
Inside Cabin	Naphthalene	217	44.1	<0.0009 ppm
Outside rear center	Naphthalene	207	41.5	<0.0009 ppm
Outside rear center	Naphthalene	208	40.6	<0.0009 ppm
Inside Cabin	Propylene glycol	222	440	<0.002 mg/m^3
Outside rear center	Propylene glycol	206	401	(0.012 mg/m^3)
Inside Cabin	Toluene	218	43.3	(0.0028 ppm)
Inside Cabin	Toluene	217	44.1	(0.0029 ppm)
Outside rear center	Toluene	207	41.5	<0.001 ppm
Outside rear center	Toluene	208	40.6	<0.001 ppm
Inside Cabin	Total hydrocarbons	218	43.3	0.62 mg/m^3
Inside Cabin	Total hydrocarbons	217	44.1	0.63 mg/m^3
Outside rear center	Total hydrocarbons	207	41.5	0.059 mg/m^3
Outside rear center	Total hydrocarbons	208	40.6	0.12 mg/m^3
Inside Cabin	Total particulates	223	442	<0.09 mg/m^3
Inside Cabin	Xylenes	218	43.3	(0.0027 ppm)
Inside Cabin	Xylenes	217	44.1	(0.0028 ppm)
Outside rear center	Xylenes	207	41.5	<0.002 ppm
Outside rear center	Xylenes	208	40.6	<0.002 ppm

*N/A = not applicable

†Concentrations reported as "<" were not detected; the given value is the minimum detectable concentration

‡Concentrations in parentheses were between the minimum detectable concentration and the minimum quantifiable concentration (parentheses are used to point out there is more uncertainty associated with these values than values above the minimum quantifiable concentration)

Table 9. Personal breathing zone and area air concentrations for substances measured on June 16, 2010 on the St. Martin

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Personal Breathing Zone Air Samples—Worker A§				
Deckhand	Benzene soluble fraction	224	434	<0.2 mg/m^3
Deckhand	Total particulates	224	434	<0.09 mg/m^3
Personal Breathing Zone Air Samples—Worker B§				
Deckhand	Benzene	221	44.3	<0.002 ppm
Deckhand	Benzene	220	43.0	<0.002 ppm
Deckhand	Ethyl benzene	221	44.3	<0.001 ppm
Deckhand	Ethyl benzene	220	43.0	<0.001 ppm
Deckhand	Limonene	221	44.3	0.011 ppm
Deckhand	Limonene	220	43.0	0.011 ppm
Deckhand	Naphthalene	221	44.3	<0.0009 ppm
Deckhand	Naphthalene	220	43.0	<0.0009 ppm
Deckhand	Toluene	221	44.3	(0.0041 ppm)
Deckhand	Toluene	220	43.0	(0.0044 ppm)
Deckhand	Total hydrocarbons	221	44.3	0.59 mg/m^3
Deckhand	Total hydrocarbons	220	43.0	0.58 mg/m^3
Deckhand	Xylenes	221	44.3	(0.0035 ppm)
Deckhand	Xylenes	220	43.0	(0.0034 ppm)
Area Air Samples				
On deck	Benzene	225	44.3	<0.002 ppm
On deck	Benzene	224	43.8	<0.002 ppm
In cabin	Benzene	217	43.6	<0.002 ppm
On deck	Benzene soluble fraction	229	449	<0.2 mg/m^3
In cabin	Benzene soluble fraction	215	429	<0.2 mg/m^3
On deck	Carbon Monoxide	235	N/A	Range: 0–4 ppm; Avg: 3 ppm
On deck	Diesel exhaust	230	450	EC: (1.4 µg/m^3); OC: (31 µg/m^3)
On deck	Ethyl benzene	225	44.3	<0.001 ppm
On deck	Ethyl benzene	224	43.8	<0.001 ppm
In cabin	Ethyl benzene	217	43.6	(0.0011 ppm)
On deck	Hydrogen sulfide	235	N/A	0 ppm
On deck	Limonene	225	44.3	(0.0011 ppm)
On deck	Limonene	224	43.8	(0.0013 ppm)
In cabin	Limonene	217	43.6	0.017 ppm
On deck	Mercury	214	41.6	<0.00005 ppm
On deck	Naphthalene	225	44.3	<0.0009 ppm
On deck	Naphthalene	224	43.8	(0.0010 ppm)
In cabin	Naphthalene	217	43.6	(0.0021 ppm)
On deck	Propylene glycol	225	440	<0.002 mg/m^3
On deck	Toluene	225	44.3	(0.0022 ppm)
On deck	Toluene	224	43.8	(0.0016 ppm)
In cabin	Toluene	217	43.6	0.0057 ppm

Table 9. Personal breathing zone and area air concentrations for substances measured on June 16, 2010 on the St. Martin (continued)

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Area Air Samples				
On deck	Total hydrocarbons	225	44.3	0.27 mg/m^3
On deck	Total hydrocarbons	224	43.8	0.30 mg/m^3
In cabin	Total hydrocarbons	217	43.6	0.85 mg/m^3
On deck	Total particulates	229	449	<0.09 mg/m^3
In cabin	Total particulates	215	429	<0.09 mg/m^3
On deck	Xylenes	225	44.3	(0.0029 ppm)
On deck	Xylenes	224	43.8	(0.0032 ppm)
In cabin	Xylenes	217	43.6	(0.0042 ppm)

*N/A = not applicable

†Concentrations reported as "<" were not detected; the given value is the minimum detectable concentration

‡Concentrations in parentheses were between the minimum detectable concentration and the minimum quantifiable concentration (parentheses are used to point out there is more uncertainty associated with these values than values above the minimum quantifiable concentration)

Table 10. Area air concentrations for substances measured on June 20, 2010 on the Miss Carmen

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Area Air Samples				
Rear deck center	Benzene	345	69.0	<0.001 ppm
Rear deck center	Benzene soluble fraction	343	711	<0.07 mg/m^3
Rear deck center	2-Butoxyethanol	304	61.1	< 0.0007 ppm
Rear deck center	Carbon Monoxide	343	N/A	Range: 0–6 ppm; Avg: 4 ppm
Inside cabin	Carbon Monoxide	357	N/A	Range: 0–4 ppm; Avg: 2 ppm
Rear deck center	Diesel exhaust	342	706	EC: 9.1.4 µg/m^3; OC: <10 µg/m^3
Rear deck center	Dipropylene glycol butyl ether	304	61.1	(0.0060 ppm)
Rear deck center	Dipropylene glycol methyl ether	304	61.1	<0.001 ppm
Rear deck center	Ethanol	345	69.0	<0.003 ppm
Rear deck center	Ethyl benzene	345	69.0	<0.0007 ppm
Rear deck center	Limonene	345	69.0	<0.0005 ppm
Rear deck center	Naphthalene	345	69.0	<0.0006 ppm
Rear deck center	Propylene glycol	338	670	<0.001 mg/m^3
Rear deck center	Toluene	345	69.0	<0.0008 ppm
Rear deck center	Total hydrocarbons	345	69.0	(0.0086 mg/m^3)
Rear deck center	Total particulates	343	711	<0.04 mg/m^3
Rear deck center	Xylenes	345	69.0	<0.001 ppm

*N/A = not applicable

†Concentrations reported as "<" were not detected; the given value is the minimum detectable concentration

‡Concentrations in parentheses were between the minimum detectable concentration and the minimum quantifiable concentration (parentheses are used to point out there is more uncertainty associated with these values than values above the minimum quantifiable concentration)

Interim Report #4B
Evaluation of Health Effects in Workers Performing Oil Skimming from Floating City #1, Louisiana, June 19–23, 2010

Lead Author: Christine West
Contributing Authors: John Gibbins and Charles Mueller

Introduction

To better assess health symptoms among off-shore response workers, NIOSH investigators traveled to Floating City #1 on June 19–23, 2010 to collect self-administered health symptom surveys from two types of workers involved in off-shore oil skimming: 130 contracted laborers ("responders") who were responsible for oil clean-up work, and more than 300 shrimp boat captains and deck hands, who operated the approximately 125 boats taking part in the operations. Each boat had a captain, one or two deck hands, and one or two responders. The responders were temporarily housed on Floating City #1 located 10 miles northeast of Venice, Louisiana, at the mouth of the Baptiste Collette channel. Each morning and evening, responders were transported to and from the shrimp boats deployed southwest of Floating City #1 by crew boats. Their 12-hour work shifts included travel time as well as time spent on the shrimp boats. Shrimp boat captains and deck hands did not return to Floating City #1 but remained on their boats overnight.

Methods

Surveys, available in English and Spanish, were collected from responders at the end of their workday as they gathered for dinner on the floating city. The following morning, surveys and sealable envelopes were given to the designated leads of responder teams to distribute to captains and deck hands, collect before leaving the work area, and return to NIOSH investigators at the floating city at the end of the day. Workers were asked to report symptoms they experienced while working during response activities.

Results

One hundred twenty-one (93%) of 130 responders and 68 (18%) of 370 eligible captains and deck hands completed the health symptom survey. Demographically, the age and sex distributions of the two groups were similar to each other and to a comparison group of participants (who had been recruited from the Venice Field Operations Branch and the Venice Commanders' Camp and reported that they had not worked on boats and had no exposures to oil, dispersant, cleaner, or other chemicals) (See Table 1.).

Reported symptoms, grouped by type, are presented in Table 2, which includes symptoms for responders, captains, and deck hands, and the comparison group of workers. Overall, the most frequently reported symptoms by all groups were upper respiratory irritation and headaches. Scrapes and cuts were the most frequently reported injuries among responders. Although the survey did not have a question about smoking status, NIOSH investigators noted that a large number of the response workers on the floating city were smoking and reported that some ex-smokers said they started smoking again after beginning response work.

Summary

The types of symptoms reported among responders, captains, and deckhands were similar to those reported by response workers who reported no exposures to oil, dispersant, cleaner, or other chemicals. Symptoms related to heat exposure and upper respiratory symptoms were the most frequently reported in all groups. These types of symptoms can be related to a combination of several factors, including heat and humidity, sun exposure, psychosocial stress, and tobacco smoke. We do not believe that the symptoms reported are consistent with exposure to oil, oil constituents, or dispersants.

Although this report focuses on responders, captains, and deckhands involved in oil skimming, we would be remiss not mentioning cigarette smoking. Implementing a no-smoking policy at this late date raises ethical concerns and practical challenges; however, in the future it may be justified in light of the harms resulting from exposure to tobacco smoke and the lack of other avenues of redress for nonsmoking workers. The same legal, practical, and health issues that have driven successful efforts to make other workplaces smoke-free argue in favor of extending similar protection to emergency response workers.

Table 1. Health symptom survey–demographics by group

	BP Responders	Captains and Deck Hands	Unexposed*
Number of Participants	121	69	103
Age range	18–63	18–65	18–70
Race			
White	26%	55%	40%
Hispanic	28%	4%	29%
Asian	0	26%	9%
Black	37%	10%	19%
Other	5%	3%	3%
Not specified	3%	1%	
Male	98%	99%	96%
Days worked oil spill	1–60	0–60	0–45
Days worked boat	0–60	0–56	0

*Participants were recruited from the Venice Field Operations Branch and the Venice Commanders' Camp. Those who reported that they had not worked on boats and had no exposures to oil, dispersant, cleaner, or other chemicals were included in this group.

Table 2. Health symptom survey–reported injuries and symptoms

	BP Responders	Captains and Deck Hands	Unexposed*
Number of participants	121	69	103
Injuries			
Scrapes or cuts	12 (10%)	3 (4%)	11 (11%)
Burns by fire	0	0	1 (1%)
Chemical burns	0	0	0
Bad Sunburn	4 (3%)	1 (1%)	8 (8%)
Constitutional symptoms			
Headaches	13 (11%)	9 (13%)	5 (5%)
Feeling faint, dizziness, fatigue or exhaustion, or weakness	5 (4%)	5 (7%)	13 (13%)
Eye and upper respiratory symptoms			
Itchy eyes	5 (4%)	0	5 (5%)
Nose irritation, sinus problems, or sore throat	11 (9%)	10 (14%)	16 (16%)
Metallic taste	0	1 (1%)	0
Lower respiratory symptoms			
Coughing	8 (7%)	4 (6%)	8 (8%)
Trouble breathing, short of breath, chest tightness, wheezing	2 (2%)	2 (3%)	4 (4%)
Cardiovascular symptoms			
Fast heart beat	0	0	1 (1%)
Chest pressure	0	1 (1%)	0
Gastrointestinal symptoms			
Nausea or vomiting	3 (2%)	3 (4%)	3 (3%)
Stomach cramps or diarrhea	5 (4%)	2 (3%)	7 (7%)
Skin symptoms			
Itchy skin, red skin, or rash	5 (4%)	0	8 (8%)
Musculoskeletal symptoms			
Hand, shoulder, or back pain	3 (2%)	2 (3%)	6 (6%)
Psychosocial symptoms			
Feeling worried or stressed	2 (2%)	4 (6%)	4 (4%)
Feeling pressured	1 (1%)	1 (1%)	2 (2%)
Feeling depressed or hopeless	1 (1%)	0	1 (1%)
Feeling short tempered	0	1 (1%)	4 (4%)
Frequent changes in mood	0	1 (1%)	3 (3%)
Heat stress symptoms†			
Any	18 (15%)	12 (17%)	21 (20%)
4 or more symptoms	2 (2%)	1 (1%)	3 (3%)

*Participants were recruited from the Venice Field Operations Branch and the Venice Commanders' Camp. Those who reported that they had not worked on boats and had no exposures to oil, dispersant, cleaner, or other chemicals were included in this group.

†Headache, dizziness, feeling faint, fatigue or exhaustion, weakness, fast heartbeat, nausea, red skin, or hot and dry skin.

Interim Report #4C
Evaluation of Source Control Vessels Development Driller II and Discoverer Enterprise, June 21–23, 2010

Lead Authors: Steve Ahrenholz, Dave Sylvain, and John Gibbins
Contributing Authors: Greg Burr, Nancy Burton, Kenny Fent, Charles Mueller, and Jessica Ramsey

Introduction

On June 21–23, 2010, NIOSH investigators conducted industrial hygiene surveys and collected self-administered health symptom surveys aboard two vessels located at the site of the Deepwater Horizon Mississippi Canyon (MC) 252 Well No. 1 oil release. This site visit was part of the NIOSH response to a series of Health Hazard Evaluation (HHE) requests that were received from BP concerning workers involved in the Deepwater Horizon response.

Background

MC252 Well No. 1 is located approximately 50 miles southeast of Venice, Louisiana, at a depth of about 5,000 feet. On June 21–23, 2010, the four primary vessels at the Deepwater Horizon MC252 location were two semi-submersible drilling rigs (Development Driller II (DD II) and Development Driller III (DD III)), a drillship (Discoverer Enterprise), and a semi-submersible multipurpose oil field construction and intervention vessel (Q4000). The DD II, DD III, and Discoverer Enterprise are operated by Transocean; the Q4000 is operated by Helix Energy Solutions Group. At the time of the NIOSH evaluation, DD II and DD III were drilling relief wells for the purpose of pumping mud into the blown well to suppress the release of crude oil, followed by concrete to seal the well [BP 2010a]. The Discoverer Enterprise, which was located directly above the blown well, captured oil and gas from the damaged well through a lower marine riser package cap [BP 2010b], which was placed on top of the failed Deepwater Horizon blowout preventer (BOP). Captured oil and gas traveled through the riser insertion tube to the Discoverer Enterprise where gas was separated from the oil, and was burned at the flare boom on the starboard side of the vessel [Deepwater Horizon Unified Command 2010]. Captured oil was stored temporarily aboard the Discoverer Enterprise until it was pumped into an oil tanker. The oil storage capacity of the Discoverer Enterprise is 100,000 barrels [Net Resources International 2010]. The Q4000 draws oil and gas from the choke and kill lines on the BOP. Approximately 9,000 barrels of oil were flared each day by the Q4000. A visible plume of combustion products was generated by the Q4000 flare. The Discoverer Enterprise and Q4000 were generally positioned so that the flare booms were perpendicular to wind direction to carry combustion products away from the vessels.

Development Driller II

The DD II is a semisubmersible drilling unit with an operating water depth of 7,500 feet (ft) and a drilling depth of 37,500 ft (See Figure 1). The main deck width and length are both about 244 ft [Transocean 2010a]. The DD II went into service in 2004 [Transocean 2010b]. The rig contains all equipment and materials for drilling operations including cranes, drilling equipment, hoisting equipment, storage, drill

mud conditioning (mixing, cleaning, recirculating) and well-control equipment. The DD II was not involved with oil collection from the damaged BOP and at the time of the NIOSH evaluation was operating in drilling mode, along with DD III. The water surface distance between the DD II and the Discoverer Enterprise was about 2,400 ft; the distance to the DD III was about 2,500 ft. One hundred sixty-seven people were on board the DD II during the NIOSH evaluation. This included 95 Transocean workers, 21 Transocean third party workers, and other personnel with the client (BP) or client third party employers.

Figure 1. GSF Development Driller II. Photo courtesy Transocean Ltd.

Personnel outside of living quarters, offices, and non-hazardous interior work areas were required to wear hard hats, coveralls, gloves, hearing protection, and safety glasses. Personal flotation devices were required during activities presenting a potential for entry into the water. All personnel were required to be fit tested and were equipped with 3M 6000 series half-mask and full-facepiece air purifying respirators equipped with organic vapor/acid gas/P100 cartridges. No oil dispersion agent was used by or stored aboard the DD II. Potential for exposure to crude oil from the MC252 Well No. 1 and dispersion agent was limited to that on the water surrounding the DD II. No activities requiring contact by workers aboard the DD II with crude oil or dispersion agent containing seawater were identified by NIOSH investigators.

Discoverer Enterprise

The Discoverer Enterprise is a deepwater double-hulled dynamically positioned drillship (see Figure 2). The Discoverer Enterprise can perform a range of subsea operations including laying ultra deepwater pipelines and providing extended well testing and storage capabilities. It has an operating water depth of 10,000 ft. and a drilling depth of 35,000 ft. The vessel is 835 ft. long and 125 ft. wide with a height of 418 ft [Transocean 2010c]. The Discoverer Enterprise went into service in 1999 [Transocean 2010b]. The vessel contains dual rotary tables operating under one massive derrick. In addition to containing all the equipment and materials found on drilling rigs, the Discoverer Enterprise can collect and hold about 100,000 barrels of crude oil. At the time of the HHE, the Discoverer Enterprise was located over the damaged MC252 Well BOP and was operating in a recovery and production mode, collecting about 25,000 barrels of oil per day. The vessel had a flare boom located on the starboard side which continuously burned gases coming up with the oil captured from the lower marine riser package cap.

One hundred eighty-six people were on board during the NIOSH evaluation. The largest numbers of workers were with Transocean (93 workers), Schlumberger (22), ART Catering – [quarters operation] (19), Oceaneering – [Remotely Operated Vehicles on the ocean floor] (13), and BP (8).

Figure 2. Discoverer Enterprise. Photo courtesy of Transocean Ltd.

Personnel outside of quarters or non-hazardous work spaces were required to wear hard hats, flame retardant coveralls, gloves, hearing protection, and safety glasses. Because of the high noise level generated by the Discoverer Enterprise flare, double hearing protection (earplugs and ear muffs) was required in designated areas. Personal flotation devices were required during activities presenting a potential for entry into the water. All personnel were required to be fit tested and have in their possession 3M 6000 series half-mask and full-facepiece air purifying respirators equipped with organic vapor/acid gas/P100 cartridges. Workers on deck and in hazardous work spaces on the Discoverer Enterprise were required to carry their respirators and double hearing protection with them. The cartridges used for the air purifying respirators had been changed from organic vapor/P100 to cartridges including acid gas. This modification was implemented after the Q4000 began flaring oil and gas on June 16 [BP 2010c].

Operations aboard the Discoverer Enterprise included transfer of crude oil to oil tankers; operation of remotely operated vehicles (ROVs) near the ocean floor; collection and storage of crude oil; separation of gas from the oil; burning gas at the flare boom; and use of methanol as an anti-freezing agent at depth to reduce icing due to gas hydrate formation. NIOSH investigators were told that no dispersants had been used or stored on the Discoverer Enterprise. Application of dispersion agent was performed on an as-needed basis by other vessels in the area. The dispersion agent had been applied either at the surface or injected at depth. During the NIOSH evaluation on June 23, 2010, the Discoverer Enterprise was transferring about 80,000 barrels of crude oil to the oil tanker Overseas Cascade.

Recovery and production operations aboard the Discoverer Enterprise deviated from routine activities during the NIOSH evaluation on June 23, 2010. At approximately 8 a.m., an alarm was sounded throughout the vessel implementing a muster. All nonessential personnel reported to the galley to be accounted for and to gather in groups by lifeboat assignment. Rising seawater in the riser connecting the Discoverer Enterprise to the damaged well, and through which oil was transported up to the vessel,

was occurring. This triggered concern because a decrease in the outflow of seawater from the annulus of the riser at the sea floor may indicate the presence of gas accumulation in the riser and a potential loss of control over the well. Personnel were required to remain at the vessel's muster location until corrective actions were taken to address the immediate concern. Difficulty discerning the cause of rising seawater in the riser prompted implementation of protective measures and an emergency disconnect of the riser from the well. Further investigation disclosed that there was no gas in the riser. A discharge valve on the riser near the collection point at the well had inadvertently been closed resulting in a malfunction. Following the identification and correction of the malfunction, the Discoverer Enterprise riser was reconnected to the well, and resumption of operations and oil collection occurred at approximately 7:50 p.m.

BP Offshore Air Monitoring Activities for Source Control

Monitoring for personal and area airborne concentrations of various contaminants was conducted by Total Safety air monitoring technicians. BP's OFFSHORE Air Monitoring Plan for Source Control, June 11, 2010 revision, was used to direct monitoring activities on the DD II and the Discoverer Enterprise. Two technicians were assigned to the DD II and six to the Discoverer Enterprise. The technicians worked with the vessel operators to select real-time monitoring locations in common work areas and inside crew quarters. In addition, technicians could place additional monitors at other locations or areas of interest (such as the edge of the vessel or by the moon pool [an opening in the hull of the vessel giving access to the water below]) to gain early indications of rising lower explosive limit (LEL) levels [BP 2010d]. Pictures of the moon pools for the DD II and the Discoverer Enterprise are shown in Figures 3 and 4.

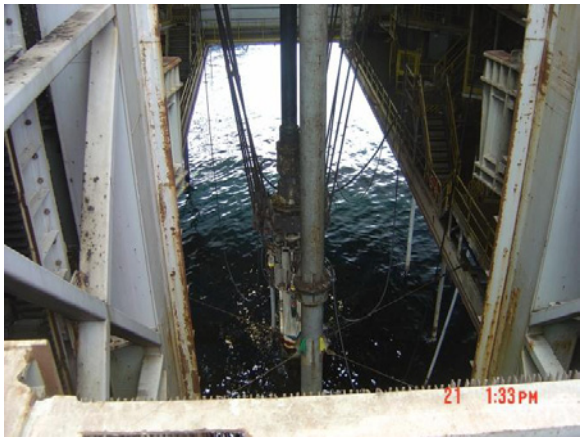

Figure 3. DD II lower moon pool.

Figure 4. Discoverer Enterprise moon pool main deck.

Airborne contaminants and atmospheric hazards monitored on the vessels by BP were: volatile organic compounds (VOCs), LEL (calibrated for methane), percent oxygen, hydrogen sulfide (H_2S), carbon monoxide (CO), benzene, sulfur dioxide (SO_2), and particulate matter less than 10 micrometers (µm) aerodynamic diameter (PM10). These latter two contaminants were measured for source control vessels (Discoverer Enterprise and Q4000) that were burning gas or gas and oil as part of containment or production activities. Air monitoring for VOCs was conducted using AreaRAE Steel (Rae Systems, San Jose, California) photo-ionization detectors (PID). An UltraRAE (RAE Systems, San Jose, California) PID monitor, which was specific for benzene, was used when elevated VOC levels were detected. This unit

combines an ultraviolet lamp that is energy specific for benzene with a proprietary RAE-Sep™ benzene tube [RAE Systems 2010]. PM10 levels were obtained using stationary or portable Thermo (Thermo Environmental Instruments, Franklin, Massachusetts) or TSI (Shoreview, Minnesota) PM10 data logging monitors. LEL was evaluated with a catalytic bead sensor; electrochemical sensors were used to monitor percent oxygen, H_2S, and CO [BP 2010d].

Personal breathing zone (PBZ) air sampling for benzene and VOCs was conducted using passive organic vapor monitors (OVMs) that were submitted for laboratory analyses. OVM badges were placed on personnel identified as having the highest potential for exposure [BP 2010d]. The majority of environmental and personal exposure measurements collected on the DD II and Discoverer Enterprise and provided to NIOSH investigators were below the lowest of the stepped BP action levels triggering corrective measures. The lowest action levels were 50 parts per million (ppm) for VOCs, 0.5 ppm for benzene, 25 ppm for CO, 5 ppm for H_2S, 1 ppm for SO_2, and 0.35 milligrams per cubic meter of air (mg/m^3)for PM10 [BP 2010e]. Readings at these action levels triggered corrective measures that included using water cannons to break up sheen, relocating nonessential personnel within the vessel, donning respirators, and re-orienting the vessel into the wind. Higher readings that exceeded the top-tier action levels required additional measures, e.g., moving the vessel off location (VOCs ≥ 1,000 ppm; benzene ≥ 10 ppm in living quarters), immediate evacuation of work area (CO ≥ 25 ppm; H_2S ≥ 5 ppm), shutdown of flaring operations (SO_2 ≥ 100 ppm), and donning full-facepiece respirators fitted with organic vapor/acid gas/P100 cartridges (PM10 ≥ 2.5 mg/m^3). Levels of VOCs, benzene, and SO_2 aboard the Discoverer Enterprise were negligible the afternoon of June 23. PM10 values were below the action level except for the measurement at 4:00 p.m., which was recorded at 0.278 mg/m^3 [Ahrenholz 2010a].

Airborne concentration data collected by BP and made available to NIOSH indicated that the contaminants identified in the previous paragraph were generally low compared to OELs. Worker exposure monitoring by BP was obtained primarily through the use of passive dosimeters. Direct reading instrumentation was used for most of the sampling on the vessels. The active integrated sampling conducted by NIOSH investigators sought to evaluate the primary contaminants of concern as well as allow for analysis of additional contaminants that might be present and were compatible with the sampling and analytical methods. Findings from other NIOSH evaluations during the Deepwater Horizon response were used to develop the exposure assessment for these two source vessels. Information provided by BP classifies the oil from MC252 as “light sweet crude” indicating that it is a form of petroleum that contains exceptionally high amounts of the chemicals needed to produce gasoline, kerosene, and high quality crude oil. The “sweet” designation describes sulfur content and that this is a low sulfur crude oil [BP 2010f].

Evaluation

NIOSH investigators conducted PBZ and area air sampling aboard the DD II on June 21 and aboard the Discoverer Enterprise on June 23, 2010. A BP industrial hygienist and a Transocean health, safety, and environment advisor accompanied NIOSH investigators and helped facilitate the NIOSH evaluation. NIOSH investigators and the BP and Transocean representatives were quantitatively fit tested for and issued respiratory protection (half-mask and full facepiece respirators) by a BP contractor at the Houma, Louisiana, heliport before they were permitted to travel out to the vessels. This provided an opportunity to observe the respirator fit testing and individual issue processes in use for all employees and visitors to the offshore vessels.

Both vessels were in continuous operation 24 hours per day. Workers on both vessels worked 12-hour shifts, either 6:00 to 6:00 or 12:00 to 12:00, depending upon whether they were part of the Marine and Maintenance Crews or the Drill and Deck Crews. The work rotation was 2 weeks on and 2 weeks off and NIOSH investigators were informed that the rigs would be changing to a 3 week rotation. NIOSH investigators asked for assistance in identifying workers whose jobs required them to spend more time out on the deck or working in areas of the vessel that had greater potential for exposure to volatile compounds associated with the crude oil.

NIOSH investigators conducted air sampling on these vessels to help characterize exposures of workers who were nearest to the point-of-release where the VOC content of the oil was expected to be greatest. Unlike crews and cleanup workers aboard the Vessels of Opportunity, and cleanup workers onshore, the crews of the DD II and Discoverer Enterprise were performing operations that utilized their usual and standard work skills, PPE, training, and experience, i.e., well drilling aboard the DD II, and storage and processing of crude oil aboard the Discoverer Enterprise. NIOSH investigators surmised that the only source of non-routine occupational exposures aboard these vessels to which the crews might have been exposed was oil on the sea surface that had been released from the blown well.

To evaluate the presence of VOCs, NIOSH industrial hygienists conducted air sampling with (1) multi-sorbent thermal desorption tubes followed by thermal desorption/gas chromatography-mass spectrometry (NIOSH Method 2549), and (2) activated charcoal tubes (NIOSH method 1501 modified; NIOSH method 1550). Thermal desorption tube results were used to select specific VOCs for quantitation in PBZ and area air samples that were collected using charcoal tubes. Sulfinert®-treated thermal desorption tubes were used to assess the presence of sulfur compounds, e.g., sulfides. Other compounds measured in PBZ and area air samples using integrated air sampling techniques included propylene glycol ethers (NIOSH method 1403 modified) and polynuclear aromatic hydrocarbons (PAHs) (NIOSH method 5506), a class of more than 100 compounds that generally occur as complex mixtures. PAHs are formed during the incomplete combustion of coal, oil, gas, and other organic substances.

All samples were kept cold while aboard the vessels and during shipment to the laboratory. All pumps were calibrated before and after each sampling period.

Direct-reading measurements were obtained for CO and H_2S. Two bulk samples of drilling mud from DD II and four bulk samples of crude oil from the Discover Enterprise were obtained for headspace analysis of VOCs. Initial bulk sample analyses were used to identify and confirm the presence of selected contaminants chosen for exposure analyses prior to analyzing for specific compounds on air samples. The bulk sample results will be included in the final NIOSH HHE report. Area sampling for diesel exhaust particulate matter was planned; however, the sampling pump was damaged and could not be used. See Table 1 for a complete listing of sampling and analytical methods used [NIOSH 2010a].

All industrial hygiene equipment used on the vessels had to be certified as intrinsically safe by Underwriters Laboratories, Inc. Because intrinsic safety certification could not be verified for the HOBO® H8 ProSeries data logging temperature and relative humidity monitors typically used by NIOSH investigators [Onset Computer Corporation, Bourne, Massachusetts], these instruments were not used aboard the vessels. Weather data was obtained from the Discoverer Enterprise for June 21 and 23, 2010.

Because of concerns about possible acute health effects among workers, NIOSH industrial hygienists distributed health symptom surveys to workers aboard both vessels. Surveys were provided to workers who agreed to wear NIOSH air sampling equipment and take the survey. Additionally, surveys and return envelopes were given to Transocean and BP management representatives for distribution to crew members aboard both vessels. Completed forms in sealed envelopes were collected by the NIOSH industrial hygienists during the time they were present on each vessel.

Development Driller II

Sampling aboard DD II began at 3:00 p.m. on June 21, 2010, following mandatory in-briefings and orientation for the NIOSH investigators, and an opening conference with Transocean and BP representatives. Individuals who worked outdoors on-deck were identified and were asked to wear sampling pumps and direct-reading instruments. Job titles of sampled workers were roustabout (5), floor hand (1), rotary floor foreman/lead floor hand (1), crane operator (1), and assistant driller (1). PBZ samples were collected for the remainder of the 12:00 p.m. to 12:00 a.m. shift (437 to 491 minute sampling period). Area samples were collected at the lower moon pool, wire line deck, well test, and at a pipe manifold outside near the drill shack.

Discoverer Enterprise

Full-shift PBZ air sampling was conducted throughout the 6:00 a.m. to 6:00 p.m. shift on June 23, 2010. Individuals who worked outdoors were identified and asked to wear sampling pumps and direct-reading instruments. The job titles of sampled workers were well-test field technician (1), floor hand (2), Chief Mate (1), fire technician (2), Superintendent of ROVs (1), electrician (1), motorman (1), and air monitoring technician (1). The full-shift sample for the floor hand was collected on two individuals: one was sampled from 6:00 a.m. until the end of the shift at 12:00 p.m., and the other was sampled from 12:00 p.m. on the following shift; thus, the floor hand results are reported in half-shift segments for each of the two floor hands. The duration of the PBZ samples was 304 to 771 minutes. Area samples were collected at the moon pool and on the well test deck.

The normal work routine was interrupted at 8:00 a.m. due to indications that flammable gas might be entering the riser from the blown well. Non-essential personnel, including some sampled workers, mustered in the galley for about 1 hour before being told to return to normal duties. The drillship was disconnected from the blown well and was moved about 200 ft from its normal location directly above the well, which caused flaring to cease on the Discoverer Enterprise. Transocean and BP representatives noted that past experience indicated airborne VOC concentrations could increase approximately 3 hours after disconnecting from the well when a larger volume of crude oil could reach the surface. The ship was reconnected to the well, and resumed capturing oil and gas at approximately 7:50 p.m.

Results and Discussion

Table 2 contains a summary of the relevant occupational exposure limits (OELs) to which results were compared. Note that OELs have not been established for some of the contaminants measured during this HHE. The lack of an OEL does not necessarily mean that a substance does not have toxic properties or interactive effects with other contaminants.

VOC screening samples were collected at the moon pools on both vessels using three-bed thermal desorption tubes and two-bed Sulfinert-treated thermal desorption tubes. Low concentrations of VOCs were detected on both vessels. The most abundant compounds identified were C_{10}–C_{16} aliphatic hydrocarbons. Other compounds detected in screening samples included ethylene glycol, 2-butoxyethanol, benzaldehyde, and phenol. Blank Sulfinert-treated tubes contained trace amounts of several contaminants. The ambient temperature and relative humidity (RH) was 84°F and 82% RH on June 21, and 85°F and 82% RH on June 23, 2010.

Development Driller II

Charcoal tube air samples obtained on DD II were quantitatively analyzed for benzene, ethyl benzene, toluene, xylenes, limonene, naphthalene, dipropylene glycol butyl ether, dipropylene glycol methyl ether, and total hydrocarbons (as n-hexane). PBZ results are shown in Table 3 for four workers identified by letters A through D. Area sample results are shown on the last page of Table 3. Airborne concentrations of all sampled compounds were well below relevant OELs.

Volatile Organic Compounds
Benzene, ethyl benzene, and naphthalene were not detected in PBZ or area air samples collected on charcoal tubes on the DD II. Toluene was detected below the minimum quantifiable concentration (MQC) in an area air sample on the wire line deck, but was not detected in any of the PBZ air samples. Xylenes were present below the MQC in two PBZ air samples and in the area air sample on the wire line deck. Limonene was detected below the MQC in two PBZ air samples and was not detected above the minimum detectable concentration (MDC) in the other two PBZ air samples. Limonene was present in a quantifiable concentration (0.032 ppm) on the wire line deck, but was not detected in the area air sample at the pipe manifold. Limonene was below the MQC in two PBZ air samples, and not detected in the other two PBZ air samples. Total hydrocarbons (THCs) were quantified in all PBZ and area air samples. PBZ air samples for THCs ranged from 0.5 to 1.1 mg/m^3; the two area air samples had concentrations of 0.16 and 9.3 mg/m^3. The highest THC concentration was measured on the wire line deck where several other area samples found detectable or quantifiable concentrations of other airborne compounds.

2-Butoxyethanol and Dipropylene Glycol Ethers
NIOSH laboratory support analyzed for dipropylene glycol butyl ether, a component in COREXIT® EC9500A [Nalco 2010], the dispersant that was injected consistently underwater near the point-of-release by a nearby support vessel, Skandi Neptune, during the June 21–23, 2010, period. Dispersant was applied at the surface only on June 21, 2010, from 4:00 a.m. to 9:00 a.m. [Ahrenholz 2010b]. Some disruptions in dispersant application occurred at 9:30 a.m., 1:00 p.m., and between 5:00 p.m. and 7:00 p.m. No dispersants were used or applied by workers aboard the DD II or the Discoverer Enterprise. 2-butoxyethanol was identified in the thermal desorption tube screening samples and was subsequently quantified in some of the air samples.

2-butoxyethanol concentrations in PBZ air samples ranged from 0.029 to 0.28 ppm. The highest concentration was quantified in the sample collected on the rotary foreman while working on the rig floor. A review of drilling mud component material safety data sheets did not disclose any 2-butoxyethanol containing materials. The area air sample obtained on the wire line deck indicated 0.30 ppm; the area sample nearest to the ocean surface at the lower moon pool was below the MQC. Neither

dipropylene glycol butyl ether nor dipropylene glycol methyl ether were detected in any of the PBZ or area air samples.

Polynuclear Aromatic Hydrocarbons
PBZ air samples were obtained for five workers (labeled as E through I in Table 3). No area air samples were collected. Total PAHs were calculated as the sum of the peaks for the 17 individual compounds shown in Table 3. Total PAHs values were field blank corrected. The total PAHs for each sample were quantitated as naphthalene.

Total PAHs in samples collected aboard DD II ranged from 0.0074 to 0.0096 mg/m^3 of air. Naphthalene (range: 0.00011–0.00094 ppm), phenanthrene (range: 0.0037–0.0074 mg/m^3), and pyrene (range: 0.00046–0.001 mg/m^3), were quantified in all five PBZ samples.

Fluoranthracene was quantified in the sample collected for worker G; fluorene was quantified in samples collected for workers H and I. Acenaphthene, acenapthylene, and fluoranthracene were below the MQC in samples collected for worker I; acenapthylene was detected below the MQC for worker F. Fluorene was present below the MQC for worker G.

Carbon Monoxide and Hydrogen Sulfide
The average CO concentration inside and outside the shack on the wire line deck was 1 ppm (range: 0–6 ppm). Hydrogen sulfide was not detected in the breathing zones of the four workers who wore monitors (workers E, F, G, and H), nor was H_2S detected in the single area air sample collected at the pipe manifold.

Discoverer Enterprise

Charcoal tube air samples obtained on the Discoverer Enterprise were quantitatively analyzed for the same compounds as described above for DD II, i.e., benzene, ethyl benzene, toluene, xylenes, limonene, naphthalene, dipropylene glycol butyl ether, dipropylene glycol methyl ether and total hydrocarbons (as n-hexane). PBZ results for charcoal tube samples are shown in Table 4 for five workers (A through E). Area air samples were obtained at the well test deck and the moon pool. Area air sample results are shown on the last page of Table 4. Airborne concentrations of all sampled compounds were well below relevant OELs for samples collected aboard the Discoverer Enterprise.

Volatile Organic Compounds
Benzene, ethyl benzene, and naphthalene were not detected in PBZ or area air samples collected on charcoal tubes on the Discoverer Enterprise. Toluene and xylenes were detected below the MQC in the PBZ air sample collected on the air monitoring technician (worker B), but were below the MDC in the other four PBZ air samples as well as in the two area air samples. Limonene was quantified in three PBZ air samples (workers A, B, and C), but was not detected in the other two personal samples. Limonene was detected below the MQC on the well test deck; limonene was not detected at the moon pool. THCs were quantified in all PBZ air samples on workers B through E, and area air samples. THCs in PBZ air samples ranged from 0.08 to 0.42 mg/m^3; area air samples indicated THC concentrations of 0.13 at the well test deck and 0.080 mg/m^3 at the moon pool.

2-Butoxyethanol and Dipropylene Glycol Ethers
Quantifiable concentrations of 2-butoxyethanol were measured in one PBZ air sample and in the area air sample collected on the well test deck. 2 butoxyethanol in the other four PBZ air samples and in the area air sample at the moon pool was below the MQC. Dipropylene glycol butyl ether was detected below the MQC in PBZ air samples for workers B and C. Dipropylene glycol ethers were not detected in the other samples.

Polynuclear Aromatic Hydrocarbons
PBZ air samples were obtained for five workers (labeled F through J in Table 4). No PAH area air samples were collected. Total PAHs were calculated as the sum of all peaks present in the sample. The total PAHs for each sample were quantitated as naphthalene.

Total PAHs in samples collected aboard Discoverer Enterprise ranged from 0.0048 to 0.020 mg/m^3. Naphthalene (range: 0.00026–0.11 ppm), phenanthrene (range: 0.0025–0.012 mg/m^3), and pyrene (range: 0.00050–0.0041 mg/m^3), were quantified in all five PBZ air samples.

Fluorene was quantified in the sample collected for worker G, and was detected below the MQC in the other four PBZ air samples. Acenapthylene was detected below the MQC in three PBZ air samples, and chrysene was found below the MQC in one PBZ air sample.

Carbon Monoxide and Hydrogen Sulfide
The average CO concentration displayed by the meter worn by worker I and the meter on the well test deck was 0 ppm (range, 0–5 ppm). Hydrogen sulfide was not detected in the breathing zones of the four workers who wore monitors (workers B, D, E, and J).

Observations Applicable to Both Vessels

NIOSH investigators noted two issues related to the respiratory protection program and immediately discussed their concerns with the BP and Transocean representatives accompanying them. One issue was with the respirator fit testing and issuance procedures at the Houma, Louisiana, heliport at the time of the NIOSH evaluation. The use of only one manufacturer's line of respirators to fit all personnel presented the possibility that proper respirator fit might not be attained for some workers. Another issue was the subsequent observation that a small number of workers on the vessels had facial hair that could interfere with the proper seal of a respirator. Needed corrective actions were immediately noted and corrective actions reportedly initiated by BP and Transocean representatives.

Smoking was prohibited aboard both vessels with the exception of one designated outdoor location on the Discoverer Enterprise. The potential for interference from tobacco smoke with the NIOSH exposure monitoring is not considered a problem. The use of smokeless tobacco by some workers was observed but would not affect exposure results.

Health Symptom Surveys

Twenty-eight persons on the DDII and thirty-four on the Discoverer Enterprise completed the health symptom survey. Demographically, workers on these two vessels were similar (Table 5). Reported symptoms, grouped by type, are presented in Table 6. This table includes symptoms for workers surveyed on the two vessels and a comparison group of workers recruited at the Venice Field

Operations Branch and the Venice Commanders' Camp who reported that they had not worked on boats and had no exposures to oil, dispersant, cleaner, or other chemicals.

Overall, workers aboard the DDII reported a wider variety and a higher number of health symptoms than workers from either the Discoverer Enterprise or the comparison group. Injuries and cardiovascular symptoms were very low aboard both vessels. Headache and heat stress symptoms were reported among workers on both vessels, while symptoms of feeling worried, stressed, and pressured were highest among workers aboard the DDII. Thirty-two percent of DDII workers reported feeling worried or stressed compared to 6% on the Discoverer Enterprise and 4% in the comparison group.

Summary

Exposure assessments at the source provided an opportunity to evaluate potential contaminants associated with the oil release. Work activities on the DD II and the Discoverer Enterprise involved operations typical of offshore oil well development and oil collection but were occurring in the context of the explosion that killed 11 workers and released an unprecedented amount of oil into the Gulf of Mexico.

NIOSH investigators and others involved in the Deepwater Horizon response postulated that workers on the source control vessels had the greatest potential for exposure to contaminants from the oil. Their proximity to the source made them the most likely group to be exposed to the volatile crude oil constituents released to the atmosphere above the damaged well. Additionally, conditions on the vessels providing enclosures or conduits for chemical vapors, such as the moon pool of the Discoverer Enterprise, could provide opportunities for increased exposure. Flares on two source vessels, one on the Discoverer Enterprise and the other on the Q4000, created possible exposures to combustion by-products. Potential for worker exposure to dispersants, however, was considered to be to be less likely than for other response workers.

Airborne concentrations for all contaminants evaluated on the DD II and the Discoverer Enterprise were well below (< 10% and often substantially less than 10% of) applicable OELs. Although the number of workers sampled was relatively small, samples were collected from those thought to have the greatest exposure potential, i.e., working on open decks and directly involved with relief well drilling (DD II) or collecting oil coming through the riser from the damaged well (Discoverer Enterprise). Although NIOSH investigators were told that VOC levels might increase as a result of the non-routine events on the day of their exposure monitoring, no such increase was evident in the sampling results.

PBZ air sampling results for nine workers on the DD II resulted in 69% (90) of the 130 analyses for specific contaminants to be below detectable levels. Samples with detectable contamination had results ranging from below the minimum quantifiable concentration to an amount that was quantifiable but very low. CO and H_2S concentrations were negligible (0–6 ppm CO) or zero (CO and H_2S). The four sets of area samples reflected the same proportion of nondetectable concentrations.

PBZ air sampling results for 10 workers on the Discoverer Enterprise resulted in 67% (94) of the 140 analyses for specific contaminants to be below detectable levels. Samples with detectable contamination had results ranging from below the minimum quantifiable concentration to a concentration that was quantifiable but very low. CO and H_2S values were negligible (0–6 ppm for CO) or

zero (CO and H_2S). In the two sets of area samples, 75% of the 20 contaminant-specific analyses were below detectable levels.

One issue to consider in interpreting these findings is the fact that the results are compared to OELs unadjusted for actual work schedules. The source control vessels operated on 12 hour, 7 day per week schedules with workers working 2 or 3 week-long rotations. Downward adjustment of the OELs, however, would not change the findings or determination for the days monitored due to the fact that all exposures were very low.

The NIOSH evaluation did not identify overexposures to contaminants that would necessitate routine wearing of respiratory protection; however, the immediate availability of respiratory protection is appropriate in this work environment because of the potential for an upset in operations, uncharacterized chemical releases, and sporadic releases of chemicals that may approach targeted action levels. Continuous on-board monitoring for contaminants of concern is a reasonable strategy for this situation.

Workers aboard the DD II reported more symptoms, particularly psychosocial symptoms, than workers aboard the Discoverer Enterprise and response workers not working on vessels or with exposure to chemical hazards. In light of the lack of evidence for significant chemical exposures, variations in rates of physical symptoms may be related to other factors (occupational and non-occupational) or may represent random variation. Because heat stress symptoms were reported aboard both vessels, BP should maintain the Deepwater Horizon Off-shore Clean-up Task Force Heat Stress Management Plan, with re-evaluation and modification as necessary based on conditions.

Thirteen workers aboard the DD II reported feeling worried, stressed, or pressured. Many contributing factors, both occupational and non-occupational, may have led to these responses. To determine the specific factors for these work stress factors would require further study. At the time of this evaluation, oil was still leaking onto the Gulf, resulting in scrutiny and pressure to complete the relief wells as quickly as possible.

Recommendations

Although the data collected on the days of the NIOSH evaluation did not indicate the need for mandatory, routine respiratory protection, the practice of having respirators immediately available for workers during uncontrolled situations or during operations where continuous area monitoring indicates rising exposure levels should continue.

The conduct of respiratory protection fit testing and issuance of air purifying respirators at the Houma, Louisiana, heliport, as well as their adherence to BP respiratory protection program requirements, needs to be reassessed and corrections implemented. The ability to adequately protect workers with one respirator line from one manufacturer is a questionable practice [OSHA 2004]. Identification and selection of an alternate model of air purifying respirator is needed. Although this does present challenges regarding respirator inventory and use, all workers need to be provided effective respiratory protection.

The respirator fit testing process also provides a teachable moment for workers that should be better utilized. Information to be covered should include limitations of respiratory protection, proper donning

and doffing procedures, indicators of the need for changing respirator cartridges, and proper storage and cleaning of respirators. Restrictions concerning facial hair and the ability to use air purifying respirators should be re-iterated to all workers where the potential to use respiratory protection is required. Although a worker may be clean-shaven on the day he reports to a source vessel, he needs to maintain this status over the course of the 2–3 week work rotation aboard the vessel.

The appropriateness of applying unadjusted OELs to worker exposures obtained for 12 hour, 7 day per week work schedules should be reevaluated for these operations. Consideration should be given to identifying the appropriate OELs for comparing full shift exposures and for deriving action levels that trigger additional exposure reduction measures [NIOSH 2010b]. Transition from the current 2 week rotation to a 3 week rotation may have the potential to further complicate contaminant exposures. Ross [2009] in his review of offshore industry shift work also notes that there may be a potential for increased severity of injuries once shifts are extended beyond 12 hours in duration or tours of duty extended beyond the UK sector practice of 2 weeks.

Because heat stress symptoms were reported aboard both vessels, BP should maintain the Deepwater Horizon Off-shore Clean-up Task Force Heat Stress Management Plan, with re-evaluation and modification as necessary based on conditions.

BP and its contractors might consider a special emphasis follow-up with regard to EAP services for the workers on the source control, given our survey results regarding stress on the DDII. We are aware that BP employees always have access to BP's EAP Hotline, and confidential counseling services whether employees are on or off-rotation.

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Table 1. Analytical methods used aboard Development Driller II and Discoverer Enterprise, June 21–23, 2010

Analyte	Method
Benzene	NMAM† 1501‡
Carbon monoxide	Direct reading—GasAlert CO Extreme, BW Technologies Ltd., Calgary, Canada
Ethyl benzene	NMAM 1501‡
Glycol ethers (2-Butoxyethanol, Dipropylene glycol butyl ether, Dipropylene glycol methyl ether)	NMAM 1403‡
Hydrogen sulfide	Direct reading—GasAlert H_2S Extreme, BW Technologies Ltd., Calgary, Canada
Limonene	NMAM 1501‡
Naphthalene	NMAM 1501‡
Polynuclear aromatic hydrocarbons	NMAM 5506
Toluene	NMAM 1501‡
Total hydrocarbons	NMAM 1501‡
Volatile organic compounds (Screening)	NMAM 2549
Xylenes, total	NMAM 1501‡

†National Institute for Occupational Safety and Health (NIOSH) Manual of Analytical Methods [NIOSH 2010a]
‡Analysis for selected volatile organic compounds by an adaptation of the method

Table 2. Occupational exposure limits for substances evaluated aboard Development Driller II and Discoverer Enterprise, June 21–23, 2010

Chemical	NIOSH REL[a]	OSHA PEL[b]	ACGIH TLV[c]	AIHA WEEL[d]
Benzene	0.1 ppm TWA[e] 1 ppm STEL[f]	1 ppm TWA 5 ppm STEL 0.5 ppm Action Level	0.5 ppm TWA 2.5 ppm STEL	N/A[g]
2-Butoxyethanol	5 ppm TWA	50 ppm TWA	20 ppm TWA	N/A
Carbon monoxide	35 ppm TWA 200 ppm Ceiling	50 ppm TWA	25 ppm TWA	N/A
Dipropylene glycol butyl ether	N/A	N/A	N/A	N/A
Dipropylene glycol methyl ether	100 ppm TWA 150 ppm STEL	100 ppm TWA	100 ppm TWA 150 ppm STEL	N/A
Ethyl benzene	100 ppm TWA 125 ppm STEL	100 ppm TWA	100 ppm TWA[h] 125 ppm STEL	N/A
Hydrogen sulfide	10 ppm Ceiling (10 min max)	20 ppm Ceiling[i]	1 ppm TWA 5 ppm STEL	N/A
Limonene	N/A	N/A	N/A	30 ppm TWA
Naphthalene	10 ppm TWA 15 ppm STEL	10 ppm TWA	10 ppm TWA 15 ppm STEL	N/A
Polynuclear Aromatic Hydrocarbons	N/A[j]	N/A[j]	N/A[j]	N/A
Total hydrocarbons	350 mg/m^3 TWA 1800 mg/m^3 Ceiling (Petroleum distillates)	2000 mg/m^3 TWA (Petroleum distillates as naphtha)	200 mg/m^3 TWA (Kerosene as total hydrocarbon vapor)	N/A
Toluene	100 ppm TWA 150 ppm STEL	200 ppm TWA 300 ppm Ceiling 500 ppm Peak (10 min max)	20 ppm TWA	N/A
Xylenes	100 ppm TWA 150 ppm STEL	100 ppm TWA	100 ppm TWA 150 ppm STEL	N/A

[a]National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL) [NIOSH 2005]
[b]Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) [29 CFR 1910]
[c]American Conference of Governmental Industrial Hygienists® (ACGIH) threshold limit value® (TLV) [ACGIH 2010]
[d]American Industrial Hygiene Association (AIHA) Workplace Environmental Exposure Level (WEEL) [AIHA 2010]
[e]TWA = time weighted average
[f]STEL = short term exposure limit
[g]N/A = not applicable
[h]Proposed to be changed to 20 ppm TWA and STEL eliminated [ACGIH 2010]
[i]Exposures shall not exceed with the following exception: if no other measurable exposure occurs during the 8-hour work shift, exposures may exceed 20 ppm, but not more than 50 ppm (peak), for a single time period up to 10 minutes
[j]With the exception of naphthalene, OELs are not available for the individual PAHs measured in this evaluation.

Table 3. Personal breathing zone and area air concentrations for substances measured on June 21, 2010 on the DDII

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Personal Breathing Zone Air Samples—Worker A				
Roustabout, Main Deck	Benzene	442	45.5	<0.001 ppm
Roustabout, Main Deck	2-Butoxyethanol	445	86.3	0.065 ppm
Roustabout, Main Deck	Dipropylene glycol butyl ether	445	86.3	<0.0007 ppm
Roustabout, Main Deck	Dipropylene glycol methyl ether	445	86.3	<0.0004 ppm
Roustabout, Main Deck	Ethyl benzene	442	45.5	<0.001 ppm
Roustabout, Main Deck	Limonene	442	45.5	(0.0010 ppm)
Roustabout, Main Deck	Naphthalene	442	45.5	<0.0008 ppm
Roustabout, Main Deck	Toluene	442	45.5	<0.001 ppm
Roustabout, Main Deck	Total hydrocarbons	442	45.5	0.66 mg/m^3
Roustabout, Main Deck	Xylenes	442	45.5	(0.0031 ppm)
Personal Breathing Zone Air Samples—Worker B				
Rotary Foreman/Lead Floor Hand, Rig Floor	Benzene	457	48.5	<0.001 ppm
Rotary Foreman/Lead Floor Hand, Rig Floor	2-Butoxyethanol	460	48.0	0.28 ppm
Rotary Foreman/Lead Floor Hand, Rig Floor	Dipropylene glycol butyl ether	460	48.0	<0.001 ppm
Rotary Foreman/Lead Floor Hand, Rig Floor	Dipropylene glycol methyl ether	460	48.0	<0.0007 ppm
Rotary Foreman/Lead Floor Hand, Rig Floor	Ethyl benzene	457	48.5	<0.0009 ppm
Rotary Foreman/Lead Floor Hand, Rig Floor	Limonene	457	48.5	<0.0007 ppm
Rotary Foreman/Lead Floor Hand, Rig Floor	Naphthalene	457	48.5	<0.0008 ppm
Rotary Foreman/Lead Floor Hand, Rig Floor	Toluene	457	48.5	<0.001 ppm
Rotary Foreman/Lead Floor Hand, Rig Floor	Total hydrocarbons	457	48.5	1.1 mg/m^3
Rotary Foreman/Lead Floor Hand, Rig Floor	Xylenes	457	48.5	<0.002 ppm

Table 3. Personal breathing zone and area air concentrations for substances measured on June 21, 2010 on the DDII (continued)

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Personal Breathing Zone Air Samples—Worker C				
Roustabout, Main Deck	Benzene	451	47.5	<0.001 ppm
Roustabout, Main Deck	2-Butoxyethanol	450	47.9	0.082 ppm
Roustabout, Main Deck	Dipropylene glycol butyl ether	450	47.9	<0.001 ppm
Roustabout, Main Deck	Dipropylene glycol methyl ether	450	47.9	<0.0007 ppm
Roustabout, Main Deck	Ethyl benzene	451	47.5	<0.001 ppm
Roustabout, Main Deck	Limonene	451	47.5	<0.0008 ppm
Roustabout, Main Deck	Naphthalene	451	47.5	<0.0008 ppm
Roustabout, Main Deck	Toluene	451	47.5	<0.001 ppm
Roustabout, Main Deck	Total hydrocarbons	451	47.5	0.50 mg/m^3
Roustabout, Main Deck	Xylenes	451	47.5	(0.0026 ppm)
Personal Breathing Zone Air Samples—Worker D				
Floor Hand, Rig Floor	Benzene	461	48.8	<0.001 ppm
Floor Hand, Rig Floor	2-Butoxyethanol	461	48.3	0.029 ppm
Floor Hand, Rig Floor	Dipropylene glycol butyl ether	461	48.3	<0.001 ppm
Floor Hand, Rig Floor	Dipropylene glycol methyl ether	461	48.3	<0.0007 ppm
Floor Hand, Rig Floor	Ethyl benzene	461	48.8	<0.0009 ppm
Floor Hand, Rig Floor	Limonene	461	48.8	(0.015 ppm)
Floor Hand, Rig Floor	Naphthalene	461	48.8	<0.0008 ppm
Floor Hand, Rig Floor	Toluene	461	48.8	<0.001 ppm
Floor Hand, Rig Floor	Total hydrocarbons	461	48.8	1.1 mg/m^3
Floor Hand, Rig Floor	Xylenes	461	48.8	<0.002 ppm
Personal Breathing Zone Air Samples—Worker E				
Roustabout, Main Deck	Acenaphthene	468	935	<0.0001 mg/m^3
Roustabout	Acenapthylene	468	935	<0.0001 mg/m^3
Roustabout	Anthracene	468	935	<0.0001 mg/m^3
Roustabout	Benzo(a)anthracene	468	935	<0.0002 mg/m^3
Roustabout	Benzo(a)pyrene	468	935	<0.0003 mg/m^3
Roustabout	Benzo(b)fluoranthene	468	935	<0.0001 mg/m^3
Roustabout	Benzo(e)pyrene	468	935	<0.0002 mg/m^3
Roustabout	Benzo(g,h,i)perylene	468	935	<0.0002 mg/m^3
Roustabout, Main Deck	Benzo(k)fluoranthene	468	935	<0.0001 mg/m^3
Roustabout, Main Deck	Chrysene	468	935	<0.0001 mg/m^3
Roustabout, Main Deck	Dibenzo(a,h)anthracene	468	935	<0.0001 mg/m^3
Roustabout, Main Deck	Fluoranthracene	468	935	<0.0001 mg/m^3
Roustabout, Main Deck	Fluorene	468	935	<0.0001 mg/m^3
Roustabout, Main Deck	Hydrogen sulfide	493	N/A	0 ppm
Roustabout, Main Deck	Indeno(1,2,3-cd)pyrene	468	935	<0.0002 mg/m^3
Roustabout, Main Deck	Naphthalene	468	935	0.000094 ppm

Table 3. Personal breathing zone and area air concentrations for substances measured on June 21, 2010 on the DDII (continued)

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Personal Breathing Zone Air Samples—Worker E (continued)				
Roustabout, Main Deck	Phenanthrene	468	935	0.0042 mg/m^3
Roustabout, Main Deck	Pyrene	468	935	0.00046 mg/m^3
Roustabout, Main Deck	Total PAHs	468	935	0.0074 mg/m^3
Personal Breathing Zone Air Samples—Worker F				
Crane Operator, Starboard Crane	Acenaphthene	437	875	<0.00006 mg/m^3
Crane Operator, Starboard Crane	Acenapthylene	437	875	(0.00014 mg/m^3)
Crane Operator, Starboard Crane	Anthracene	437	875	<0.00006 mg/m^3
Crane Operator, Starboard Crane	Benzo(a)anthracene	437	875	<0.00009 mg/m^3
Crane Operator, Starboard Crane	Benzo(a)pyrene	437	875	<0.0002 mg/m^3
Crane Operator, Starboard Crane	Benzo(b)fluoranthene	437	875	<0.00006 mg/m^3
Crane Operator, Starboard Crane	Benzo(e)pyrene	437	875	<0.0001 mg/m^3
Crane Operator, Starboard Crane	Benzo(g,h,i)perylene	437	875	<0.0001 mg/m^3
Crane Operator, Starboard Crane	Benzo(k)fluoranthene	437	875	<0.00007 mg/m^3
Crane Operator, Starboard Crane	Chrysene	437	875	<0.00009 mg/m^3
Crane Operator, Starboard Crane	Dibenzo(a,h)anthracene	437	875	<0.00007 mg/m^3
Crane Operator, Starboard Crane	Fluoranthracene	437	875	<0.00007 mg/m^3
Crane Operator, Starboard Crane	Fluorene	437	875	0.00027 mg/m^3
Crane Operator, Starboard Crane	Hydrogen sulfide	487	N/A	0 ppm
Crane Operator, Starboard Crane	Indeno(1,2,3-cd)pyrene	437	875	<0.0001 mg/m^3
Crane Operator, Starboard Crane	Naphthalene	437	875	0.00013 ppm
Crane Operator, Starboard Crane	Phenanthrene	437	875	0.0037 mg/m^3
Crane Operator, Starboard Crane	Pyrene	437	875	0.00053 mg/m^3
Crane Operator, Starboard Crane	Total PAHs	437	875	0.0081 mg/m^3

Table 3. Personal breathing zone and area air concentrations for substances measured on June 21, 2010 on the DDII (continued)

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Personal Breathing Zone Air Samples—Worker G				
Roustabout, Main Deck	Acenaphthene	444	879	<0.0001 mg/m^3
Roustabout, Main Deck	Acenapthylene	444	879	<0.0001 mg/m^3
Roustabout, Main Deck	Anthracene	444	879	<0.0001 mg/m^3
Roustabout, Main Deck	Benzo(a)anthracene	444	879	<0.0002 mg/m^3
Roustabout, Main Deck	Benzo(a)pyrene	444	879	<0.0003 mg/m^3
Roustabout, Main Deck	Benzo(b)fluoranthene	444	879	<0.0001 mg/m^3
Roustabout, Main Deck	Benzo(e)pyrene	444	879	<0.0002 mg/m^3
Roustabout, Main Deck	Benzo(g,h,i)perylene	444	879	<0.0002 mg/m^3
Roustabout, Main Deck	Benzo(k)fluoranthene	444	879	<0.0001 mg/m^3
Roustabout, Main Deck	Chrysene	444	879	<0.0001 mg/m^3
Roustabout, Main Deck	Dibenzo(a,h)anthracene	444	879	<0.0001 mg/m^3
Roustabout, Main Deck	Fluoranthracene	444	879	0.00014 mg/m^3
Roustabout, Main Deck	Fluorene	444	879	(0.00017 mg/m^3)
Roustabout, Main Deck	Hydrogen sulfide	473	N/A	0 ppm
Roustabout, Main Deck	Indeno(1,2,3-cd)pyrene	444	879	<0.0002 mg/m^3
Roustabout, Main Deck	Naphthalene	444	879	0.00014 ppm
Roustabout, Main Deck	Phenanthrene	444	879	0.0043 mg/m^3
Roustabout, Main Deck	Pyrene	444	879	0.0010 mg/m^3
Roustabout, Main Deck	Total PAHs	444	879	0.0096 mg/m^3
Personal Breathing Zone Air Samples—Worker H				
Roustabout, Main Deck	Acenaphthene	491	972	<0.0001 mg/m^3
Roustabout, Main Deck	Acenapthylene	491	972	<0.00009 mg/m^3
Roustabout, Main Deck	Anthracene	491	972	<0.0001 mg/m^3
Roustabout, Main Deck	Benzo(a)anthracene	491	972	<0.0002 mg/m^3
Roustabout, Main Deck	Benzo(a)pyrene	491	972	<0.0003 mg/m^3
Roustabout, Main Deck	Benzo(b)fluoranthene	491	972	<0.0001 mg/m^3
Roustabout, Main Deck	Benzo(e)pyrene	491	972	<0.0002 mg/m^3
Roustabout, Main Deck	Benzo(g,h,i)perylene	491	972	<0.0002 mg/m^3
Roustabout, Main Deck	Benzo(k)fluoranthene	491	972	<0.0001 mg/m^3
Roustabout, Main Deck	Chrysene	491	972	<0.0001 mg/m^3
Roustabout, Main Deck	Dibenzo(a,h)anthracene	491	972	<0.0001 mg/m^3
Roustabout, Main Deck	Fluoranthracene	491	972	<0.0001 mg/m^3
Roustabout, Main Deck	Fluorene	491	972	0.00039 mg/m^3
Roustabout, Main Deck	Hydrogen Sulfide	508	N/A	0 ppm
Roustabout, Main Deck	Indeno(1,2,3-cd)pyrene	491	972	<0.0002 mg/m^3
Roustabout, Main Deck	Naphthalene	491	972	0.00011 ppm
Roustabout, Main Deck	Phenanthrene	491	972	0.0074 mg/m^3
Roustabout, Main Deck	Pyrene	491	972	0.00084 mg/m^3
Roustabout, Main Deck	Total PAHs	491	972	0.0083 mg/m^3
Personal Breathing Zone Air Samples—Worker I				
Assistant Driller/Rig Floor	Acenaphthene	468	931	(0.00015 mg/m^3)
Assistant Driller/Rig Floor	Acenapthylene	468	931	(0.00014 mg/m^3)

Table 3. Personal breathing zone and area air concentrations for substances measured on June 21, 2010 on the DDII (continued)

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Personal Breathing Zone Air Samples—Worker I (continued)				
Assistant Driller/Rig Floor	Anthracene	468	931	<0.0001 mg/m^3
Assistant Driller/Rig Floor	Benzo(a)anthracene	468	931	<0.0002 mg/m^3
Assistant Driller/Rig Floor	Benzo(a)pyrene	468	931	<0.0003 mg/m^3
Assistant Driller/Rig Floor	Benzo(b)fluoranthene	468	931	<0.0001 mg/m^3
Assistant Driller/Rig Floor	Benzo(e)pyrene	468	931	<0.0002 mg/m^3
Assistant Driller/Rig Floor	Benzo(g,h,i)perylene	468	931	<0.0002 mg/m^3
Assistant Driller/Rig Floor	Benzo(k)fluoranthene	468	931	<0.0001 mg/m^3
Assistant Driller/Rig Floor	Chrysene	468	931	<0.0001 mg/m^3
Assistant Driller/Rig Floor	Dibenzo(a,h)anthracene	468	931	<0.0001 mg/m^3
Assistant Driller/Rig Floor	Fluoranthracene	468	931	(0.00013 mg/m^3)
Assistant Driller/Rig Floor	Fluorene	468	931	0.00019 mg/m^3
Assistant Driller/Rig Floor	Indeno(1,2,3-cd)pyrene	468	931	<0.0002 mg/m^3
Assistant Driller/Rig Floor	Naphthalene	468	931	0.00021 ppm
Assistant Driller/Rig Floor	Phenanthrene	468	931	0.0041 mg/m^3
Assistant Driller/Rig Floor	Pyrene	468	931	0.00069 mg/m^3
Assistant Driller/Rig Floor	Total PAHs	468	931	0.0088 mg/m^3
Area Air Samples				
Wire Line Deck 4th Level	Benzene	467	49.3	<0.001 ppm
Pipe Manifold	Benzene	372	19.8	<0.003 ppm
Wire Line Deck 4th Level	2-Butoxyethanol	470	49.4	0.30 ppm
Lower Moon Pool Fore Side	2-Butoxyethanol	183	9.74	(0.0062 ppm)
Rig Level 4 Wire Line – Outside Shack Door	Carbon Monoxide	460	N/A	Range: 0–6 ppm; Avg: 1 ppm
Rig Level 4 Wire Line – Inside Shack Over Workstation	Carbon Monoxide	465	N/A	Range: 0–6 ppm; Avg: 1 ppm
Wire Line Deck 4th Level	Dipropylene glycol butyl ether	470	49.4	<0.001 ppm
Lower Moon Pool Fore Side	Dipropylene glycol butyl ether	183	9.74	<0.007 ppm
Wire Line Deck 4th Level	Dipropylene glycol methyl ether	470	49.4	<0.0007 ppm
Lower Moon Pool Fore Side	Dipropylene glycol methyl ether	183	9.74	<0.003 ppm
Wire Line Deck 4th Level	Ethyl benzene	467	49.3	<0.0009 ppm
Pipe Manifold	Ethyl benzene	372	19.8	<0.002 ppm
Pipe Manifold	Hydrogen sulfide	411	N/A	0 ppm
Wire Line Deck 4th Level	Limonene	467	49.3	0.032
Pipe Manifold	Limonene	372	19.8	<0.002 ppm

Table 3. Personal breathing zone and area air concentrations for substances measured on June 21, 2010 on the DDII (continued)

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Area Air Samples (continued)				
Wire Line Deck 4th Level	Naphthalene	467	49.3	<0.0008 ppm
Pipe Manifold	Naphthalene	372	19.8	<0.002 ppm
Wire Line Deck 4th Level	Toluene	467	49.3	(0.0012 ppm)
Pipe Manifold	Toluene	372	19.8	<0.003 ppm
Wire Line Deck 4th Level	Total hydrocarbons	467	49.3	9.3 mg/m^3
Pipe Manifold	Total hydrocarbons	372	19.8	0.16 mg/m^3
Wire Line Deck 4th Level	Xylenes	467	49.3	(0.0040 ppm)
Pipe Manifold	Xylenes	372	19.8	<0.005 ppm

*N/A = not applicable

†Concentrations reported as "<" were not detected; the given value is the minimum detectable concentration

‡Concentrations in parentheses were between the minimum detectable concentration and the minimum quantifiable concentration (parentheses are used to point out there is more uncertainty associated with these values than values above the minimum quantifiable concentration)

Table 4. Personal breathing zone and area air concentrations for substances measured on June 23, 2010 on the Discoverer Enterprise

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Personal Breathing Zone Air Samples—Worker A				
Fire Technician, Main Deck	Benzene	592	59.3	<0.002 ppm
Fire Technician, Main Deck	2-Butoxyethanol	591	59.4	(0.0016 ppm)
Fire Technician, Main Deck	Dipropylene glycol butyl ether	591	59.4	<0.002 ppm
Fire Technician, Main Deck	Dipropylene glycol methyl ether	591	59.4	<0.001 ppm
Fire Technician, Main Deck	Ethyl benzene	592	59.3	<0.002 ppm
Fire Technician, Main Deck	Limonene	592	59.3	0.0044 ppm
Fire Technician, Main Deck	Naphthalene	592	59.3	<0.001 ppm
Fire Technician, Main Deck	Toluene	592	59.3	<0.002 ppm
Fire Technician, Main Deck	Total hydrocarbons	592	59.3	0.25 mg/m^3
Fire Technician, Main Deck	Xylenes	592	59.3	<0.003 ppm
Personal Breathing Zone Air Samples—Worker B				
Air Monitor Technician	Benzene	690	69.1	<0.002 ppm
Air Monitor Technician	2-Butoxyethanol	694	69.5	(0.0022 ppm)
Air Monitor Technician	Dipropylene glycol butyl ether	694	69.5	(0.0024 ppm)
Air Monitor Technician	Dipropylene glycol methyl ether	694	69.5	<0.001 ppm
Air Monitor Technician	Ethyl benzene	690	69.1	<0.001 ppm
Air Monitor Technician	Hydrogen sulfide	704	N/A	0 ppm
Air Monitor Technician	Limonene	690	69.1	0.0038 ppm
Air Monitor Technician	Naphthalene	690	69.1	<0.001 ppm
Air Monitor Technician	Toluene	690	69.1	(0.0026 ppm)
Air Monitor Technician	Total hydrocarbons	690	69.1	0.42 mg/m^3
Air Monitor Technician	Xylenes	690	69.1	(0.0030 ppm)
Personal Breathing Zone Air Samples—Worker C				
Well Test Field Tech, Production Deck	Benzene	765	76.3	<0.002 ppm
Well Test Field Tech, Production Deck	2-Butoxyethanol	759	75.7	(0.0015 ppm)
Well Test Field Tech, Production Deck	Dipropylene glycol butyl ether	759	75.7	(0.0017 ppm)
Well Test Field Tech, Production Deck	Dipropylene glycol methyl ether	759	75.7	<0.0009 ppm
Well Test Field Tech, Production Deck	Ethyl benzene	765	76.3	<0.001 ppm
Well Test Field Tech, Production Deck	Hydrogen sulfide	757	N/A	0 ppm
Well Test Field Tech, Production Deck	Limonene	765	76.3	0.0097 ppm

Table 4. Personal breathing zone and area air concentrations for substances measured on June 23, 2010 on the Discoverer Enterprise (continued)

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Personal Breathing Zone Air Samples—Worker C (continued)				
Well Test Field Tech, Production Deck	Naphthalene	765	76.3	<0.001 ppm
Well Test Field Tech, Production Deck	Toluene	765	76.3	<0.001 ppm
Well Test Field Tech, Production Deck	Total hydrocarbons	765	76.3	0.30 mg/m^3
Well Test Field Tech, Production Deck	Xylenes	765	76.3	<0.001 ppm
Personal Breathing Zone Air Samples—Worker D				
Floor Hand, Rig Floor	Benzene	351	34.9	<0.002 ppm
Floor Hand, Rig Floor	2-Butoxyethanol	357	35.9	(0.0014 ppm)
Floor Hand, Rig Floor	Dipropylene glycol butyl ether	357	35.9	<0.002 ppm
Floor Hand, Rig Floor	Dipropylene glycol methyl ether	357	35.9	<0.0009 ppm
Floor Hand, Rig Floor	Ethyl benzene	351	34.9	<0.001 ppm
Floor Hand, Rig Floor	Hydrogen sulfide	351	N/A	0 ppm
Floor Hand, Rig Floor	Limonene	351	34.9	<0.001 ppm
Floor Hand, Rig Floor	Naphthalene	351	34.9	<0.001 ppm
Floor Hand, Rig Floor	Toluene	351	34.9	<0.002 ppm
Floor Hand, Rig Floor	Total hydrocarbons	351	34.9	0.12 mg/m^3
Floor Hand, Rig Floor	Xylenes	351	34.9	<0.003 ppm
Personal Breathing Zone Air Samples—Worker E				
Floor Hand, Rig Floor	Benzene	304	30.2	<0.002 ppm
Floor Hand, Rig Floor	2-Butoxyethanol	306	30.8	0.032 ppm
Floor Hand, Rig Floor	Dipropylene glycol butyl ether	306	30.8	<0.002 ppm
Floor Hand, Rig Floor	Dipropylene glycol methyl ether	306	30.8	<0.001 ppm
Floor Hand, Rig Floor	Ethyl benzene	304	30.2	<0.002 ppm
Floor Hand, Rig Floor	Hydrogen sulfide	304	N/A	0 ppm
Floor Hand, Rig Floor	Limonene	304	30.2	<0.001 ppm
Floor Hand, Rig Floor	Naphthalene	304	30.2	<0.001 ppm
Floor Hand, Rig Floor	Toluene	304	30.2	<0.002 ppm
Floor Hand, Rig Floor	Total hydrocarbons	304	30.2	0.08 mg/m^3
Floor Hand, Rig Floor	Xylenes	304	30.2	<0.003 ppm
Personal Breathing Zone Air Samples—Worker F				
Chief Mate, Cargo Deck	Acenaphthene	771	1550	<0.00006 mg/m^3
Chief Mate, Cargo Deck	Acenapthylene	771	1550	(0.000058 mg/m^3)
Chief Mate, Cargo Deck	Anthracene	771	1550	<0.00006 mg/m^3
Chief Mate, Cargo Deck	Benzo(a)anthracene	771	1550	<0.0001 mg/m^3
Chief Mate, Cargo Deck	Benzo(a)pyrene	771	1550	<0.0002 mg/m^3

Table 4. Personal breathing zone and area air concentrations for substances measured on June 23, 2010 on the Discoverer Enterprise (continued)

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Personal Breathing Zone Air Samples—Worker F (continued)				
Chief Mate, Cargo Deck	Benzo(b)fluoranthene	771	1550	<0.00006 mg/m^3
Chief Mate, Cargo Deck	Benzo(e)pyrene	771	1550	<0.0001 mg/m^3
Chief Mate, Cargo Deck	Benzo(g,h,i)perylene	771	1550	<0.0001 mg/m^3
Chief Mate, Cargo Deck	Benzo(k)fluoranthene	771	1550	<0.00007 mg/m^3
Chief Mate, Cargo Deck	Chrysene	771	1550	<0.00008 mg/m^3
Chief Mate, Cargo Deck	Dibenzo(a,h)anthracene	771	1550	<0.00007 mg/m^3
Chief Mate, Cargo Deck	Fluoranthracene	771	1550	<0.00008 mg/m^3
Chief Mate, Cargo Deck	Fluorene	771	1550	(0.00020 mg/m^3)
Chief Mate, Cargo Deck	Indeno(1,2,3-cd)pyrene	771	1550	<0.0001 mg/m^3
Chief Mate, Cargo Deck	Naphthalene	771	1550	0.00028 ppm
Chief Mate, Cargo Deck	Phenanthrene	771	1550	0.0059 mg/m^3
Chief Mate, Cargo Deck	Pyrene	771	1550	0.00084 mg/m^3
Chief Mate, Cargo Deck	Total PAHs	771	1550	0.012 mg/m^3
Personal Breathing Zone Air Samples—Worker G				
Fire Technician	Acenaphthene	723	1450	<0.00007 mg/m^3
Fire Technician	Acenapthylene	723	1450	(0.000083 mg/m^3)
Fire Technician	Anthracene	723	1450	<0.00007 mg/m^3
Fire Technician	Benzo(a)anthracene	723	1450	<0.0001 mg/m^3
Fire Technician	Benzo(a)pyrene	723	1450	<0.0002 mg/m^3
Fire Technician	Benzo(b)fluoranthene	723	1450	<0.00007 mg/m^3
Fire Technician	Benzo(e)pyrene	723	1450	<0.0001 mg/m^3
Fire Technician	Benzo(b)fluoranthene	723	1450	<0.00007 mg/m^3
Fire Technician	Benzo(e)pyrene	723	1450	<0.0001 mg/m^3
Fire Technician	Benzo(g,h,i)perylene	723	1450	<0.0001 mg/m^3
Fire Technician	Benzo(k)fluoranthene	723	1450	<0.00008 mg/m^3
Fire Technician	Chrysene	723	1450	<0.00009 mg/m^3
Fire Technician	Dibenzo(a,h)anthracene	723	1450	<0.00008 mg/m^3
Fire Technician	Fluoranthracene	723	1450	<0.00008 mg/m^3
Fire Technician	Fluorene	723	1450	0.00027 mg/m^3
Fire Technician	Indeno(1,2,3-cd)pyrene	723	1450	<0.0001 mg/m^3
Fire Technician	Naphthalene	723	1450	0.11 ppm
Fire Technician	Phenanthrene	723	1450	0.0025 mg/m^3
Fire Technician	Pyrene	723	1450	0.00050 mg/m^3
Fire Technician	Total PAHs	723	1450	0.0048 mg/m^3

Table 4. Personal breathing zone and area air concentrations for substances measured on June 23, 2010 on the Discoverer Enterprise (continued)

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Personal Breathing Zone Air Samples—Worker H				
Superintendant of ROV, Midship	Acenaphthene	713	1420	<0.00007 mg/m^3
Superintendant of ROV, Midship	Acenapthylene	713	1420	(0.000085 mg/m^3)
Superintendant of ROV, Midship	Anthracene	713	1420	<0.00007 mg/m^3
Superintendant of ROV, Midship	Benzo(a)anthracene	713	1420	<0.0001 mg/m^3
Superintendant of ROV, Midship	Benzo(a)pyrene	713	1420	<0.0002 mg/m^3
Superintendant of ROV, Midship	Benzo(b)fluoranthene	713	1420	<0.00007 mg/m^3
Superintendant of ROV, Midship	Benzo(e)pyrene	713	1420	<0.0001 mg/m^3
Superintendant of ROV, Midship	Benzo(g,h,i)perylene	713	1420	<0.0001 mg/m^3
Superintendant of ROV, Midship	Benzo(k)fluoranthene	713	1420	<0.00008 mg/m^3
Superintendant of ROV, Midship	Chrysene	713	1420	<0.00009 mg/m^3
Superintendant of ROV, Midship	Dibenzo(a,h)anthracene	713	1420	<0.00008 mg/m^3
Superintendant of ROV, Midship	Fluoranthracene	713	1420	0.000085 mg/m^3
Superintendant of ROV, Midship	Fluorene	713	1420	(0.00016 mg/m^3)
Superintendant of ROV, Midship	Indeno(1,2,3-cd)pyrene	713	1420	<0.0001 mg/m^3
Superintendant of ROV, Midship	Naphthalene	713	1420	0.00039 ppm
Superintendant of ROV, Midship	Phenanthrene	713	1420	0.0055 mg/m^3
Superintendant of ROV, Midship	Pyrene	713	1420	0.00092 mg/m^3
Superintendant of ROV, Midship	Total PAHs	713	1420	0.014 mg/m^3
Personal Breathing Zone Air Samples—Worker I				
Electrician	Acenaphthene	698	1410	<0.00007 mg/m^3
Electrician	Acenapthylene	698	1410	<0.00006 mg/m^3
Electrician	Anthracene	698	1410	<0.00007 mg/m^3
Electrician	Benzo(a)anthracene	698	1410	<0.0001 mg/m^3

Table 4. Personal breathing zone and area air concentrations for substances measured on June 23, 2010 on the Discoverer Enterprise (continued)

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Personal Breathing Zone Air Samples—Worker I (continued)				
Electrician	Benzo(a)pyrene	698	1410	<0.0002 mg/m^3
Electrician	Benzo(b)fluoranthene	698	1410	<0.00007 mg/m^3
Electrician	Benzo(e)pyrene	698	1410	<0.0001 mg/m^3
Electrician	Benzo(g,h,i)perylene	698	1410	<0.0001 mg/m^3
Electrician	Benzo(k)fluoranthene	698	1410	<0.00008 mg/m^3
Electrician	Carbon Monoxide	696	N/A	Range: 0–5 ppm; Avg: 0 ppm
Electrician	Chrysene	698	1410	(0.00041 mg/m^3)
Electrician	Dibenzo(a,h)anthracene	698	1410	<0.00008 mg/m^3
Electrician	Fluoranthracene	698	1410	<0.00009 mg/m^3
Electrician	Fluorene	698	1410	(0.00018 mg/m^3)
Electrician	Indeno(1,2,3-cd)pyrene	698	1410	<0.0001 mg/m^3
Electrician	Naphthalene	698	1410	0.00026 ppm
Electrician	Phenanthrene	698	1410	0.0071 mg/m^3
Electrician	Pyrene	698	1410	0.0016 mg/m^3
Electrician	Total PAHs	698	1410	0.014 mg/m^3
Personal Breathing Zone Air Samples—Worker J				
Motorman, Lower Machine Deck	Acenaphthene	574	1160	<0.00009 mg/m^3
Motorman, Lower Machine Deck	Acenapthylene	574	1160	<0.00008 mg/m^3
Motorman, Lower Machine Deck	Anthracene	574	1160	<0.00009 mg/m^3
Motorman, Lower Machine Deck	Benzo(a)anthracene	574	1160	<0.0001 mg/m^3
Motorman, Lower Machine Deck	Benzo(a)pyrene	574	1160	<0.0003 mg/m^3
Motorman, Lower Machine Deck	Benzo(b)fluoranthene	574	1160	<0.00009 mg/m^3
Motorman, Lower Machine Deck	Benzo(e)pyrene	574	1160	<0.0001 mg/m^3
Motorman, Lower Machine Deck	Benzo(g,h,i)perylene	574	1160	<0.0001 mg/m^3
Motorman, Lower Machine Deck	Benzo(k)fluoranthene	574	1160	<0.00009 mg/m^3
Motorman, Lower Machine Deck	Chrysene	574	1160	<0.0001 mg/m^3
Motorman, Lower Machine Deck	Dibenzo(a,h)anthracene	574	1160	<0.00009 mg/m^3
Motorman, Lower Machine Deck	Fluoranthracene	574	1160	<0.0001 mg/m^3
Motorman, Lower Machine Deck	Fluorene	574	1160	(0.00019 mg/m^3)

Table 4. Personal breathing zone and area air concentrations for substances measured on June 23, 2010 on the Discoverer Enterprise (continued)

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Personal Breathing Zone Air Samples—Worker J (continued)				
Motorman, Lower Machine Deck	Hydrogen sulfide	654	N/A	0 ppm
Motorman, Lower Machine Deck	Indeno(1,2,3-cd)pyrene	574	1160	<0.0001 mg/m^3
Motorman, Lower Machine Deck	Naphthalene	574	1160	0.00026 ppm
Motorman, Lower Machine Deck	Phenanthrene	574	1160	0.012 mg/m^3
Motorman, Lower Machine Deck	Pyrene	574	1160	0.0041 mg/m^3
Motorman, Lower Machine Deck	Total PAHs	574	1160	0.020 mg/m^3
Area Air Samples				
Well Test Deck	Benzene	751	75.6	<0.0008 ppm
Moon Pool	Benzene	224	22.5	<0.003 ppm
Well Test Deck	2-Butoxyethanol	751	74.9	0.0026 ppm
Moon Pool	2-Butoxyethanol	224	22.5	(0.0021 ppm)
Well Test Deck	Carbon Monoxide	744	N/A	Range: 0–5 ppm; Avg: 0 ppm
Well Test Deck	Dipropylene glycol butyl ether	751	74.9	<0.0009 ppm
Moon Pool	Dipropylene glycol butyl ether	224	22.5	<0.003 ppm
Well Test Deck	Dipropylene glycol methyl ether	751	74.9	<0.0004 ppm
Moon Pool	Dipropylene glycol methyl ether	224	22.5	<0.001 ppm
Well Test Deck	Ethyl benzene	751	75.6	<0.0006 ppm
Moon Pool	Ethyl benzene	224	22.5	<0.002 ppm
Well Test Deck	Limonene	751	75.6	(0.0011 ppm)
Moon Pool	Limonene	224	22.5	<0.002 ppm
Well Test Deck	Naphthalene	751	75.6	<0.0005 ppm
Moon Pool	Naphthalene	224	22.5	<0.002 ppm
Well Test Deck	Toluene	751	75.6	<0.0007 ppm
Moon Pool	Toluene	224	22.5	<0.002 ppm
Well Test Deck	Total hydrocarbons	751	75.6	0.13 mg/m^3
Moon Pool	Total hydrocarbons	224	22.5	0.080 mg/m^3
Well Test Deck	Xylenes	751	75.6	<0.001 ppm
Moon Pool	Xylenes	224	22.5	<0.004 ppm

*N/A = not applicable

†Concentrations reported as "<" were not detected; the given value is the minimum detectable concentration

‡Concentrations in parentheses were between the minimum detectable concentration and the minimum quantifiable concentration (parentheses are used to point out there is more uncertainty associated with these values than values above the minimum quantifiable concentration)

Table 5. Health symptom survey—demographics by vessel			
	Development Driller II*	**Discoverer Enterprise†**	**Unexposed‡**
Number of participants	28	34	103
Age range	22–60	21–55	18–70
Race			
White	71%	82%	40%
Hispanic	4%	0%	29%
Asian	0%	0%	9%
Black	21%	12%	19%
Other/Missing	4%	6%	3%
Male	96%	97%	96%
Days worked oil spill	13–70	7–65	0–45
Days worked boat	0–60	6–50	0

* Surveys were collected aboard the Development Driller II on June 21–22, 2010.

†Surveys were collected aboard the Discoverer Enterprise on June 22–23, 2010.

‡Participants were recruited from the Venice Field Operations Branch and the Venice Commanders' Camp. Those who reported that they had not worked on boats and had no exposures to oil, dispersant, cleaner, or other chemicals were included in this group.

Table 6. Health symptom survey—reported injuries and symptoms by vessel			
	Development Driller II*	**Discoverer Enterprise †**	**Unexposed‡**
Number of participants	28	34‡	103
Injuries			
Scrapes or cuts	1	1	11 (11%)
Burns by fire	0	0	1 (1%)
Chemical burns	0	0	0
Bad Sunburn	0	0	8 (8%)
Constitutional symptoms			
Headaches	7	12	5 (5%)
Feeling faint, dizziness, fatigue or exhaustion, or weakness	4	2	13 (13%)
Eye and upper respiratory symptoms			
Itchy eyes	5	5	5 (5%)
Nose irritation, sinus problems, or sore throat	5	7	16 (16%)
Metallic taste	0	0	0
Lower respiratory symptoms			
Coughing	4	1	8 (8%)
Trouble breathing, short of breath, chest tightness, wheezing	3	1	4 (4%)
Cardiovascular symptoms			
Fast heart beat	0	0	1 (1%)
Chest pressure	1	0	0
Gastrointestinal symptoms			
Nausea or vomiting	2	3	3 (3%)
Stomach cramps or diarrhea	5	0	7 (7%)
Skin symptoms			
Itchy skin, red skin, or rash	6	1	8 (8%)
Musculoskeletal symptoms			
Hand, shoulder, or back pain	3	0	6 (6%)
Psychosocial symptoms			
Feeling worried or stressed	9	2	4 (4%)
Feeling pressured	4	1	2 (2%)
Feeling depressed or hopeless	0	0	1 (1%)
Feeling short tempered	2	0	4 (4%)
Frequent changes in mood	3	0	3 (3%)
Heat stress symptoms§			
Any	8	13	21 (20%)
4 or more symptoms	2	1	3 (3%)

*Surveys were collected aboard the Development Driller II on June 21–22, 2010.

†Surveys were collected aboard the Discoverer Enterprise on June 22–23, 2010.

‡Participants were recruited from the Venice Field Operations Branch and the Venice Commanders' Camp. Those who reported that they had not worked on boats and had no exposures to oil, dispersant, cleaner, or other chemicals were included in this group.

§Headache, dizziness, feeling faint, fatigue or exhaustion, weakness, fast heartbeat, nausea, red skin, or hot and dry skin.

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